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THE APRIL SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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with comments by the publisher

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THE SCIENTIFIC MONTHLY

APRIL, 1928

THE CHEMICAL ELEMENTS INDISPENSABLE TO PLANTS

By Professor CHAS. B. LIPMAN

UNIVERSITY OF CALIFORNIA

It is a reasonable assertion that the properties of matter, animate or inanimate, are functions of the chemical constitution of the substances which they characterize. By chemical constitution I do not mean composition in the analyst's sense of that term, but the quantitative and qualitative structures to which the atoms of the chemical elements composing them contribute. Biologists seldom, and laymen almost never, are aware of the important rôle played by the patterns into which the chemical elements are cast in determining the properties and characteristics of the chemical compounds. Much less perhaps do they appreciate this same fact in its application to the properties of living matter. This is brought vividly to the mind's eye by the reflection that the atoms of even one element alone according to their arrangement in the molecule confer various properties on the molecule. One needs only remember how strikingly different in properties are diamond and graphite to apprehend the momentous differences which the mere arrangement of atoms in the molecule of one and the same element determines.

If one next considers the possibilities open for the arrangement of different atoms in a molecule of a compound of two or more elements he becomes aware of the stupendous variety of substances with widely varying properties which can thus be created. Here we have opportunity for producing substances of different properties not only through different arrangements of the same number and kinds of atoms but through different arrangements of different atoms in different numbers. When one remembers further that there are known some eighty odd chemical elements the possibility of having virtually limitless numbers of chemical substances with markedly different properties becomes bewildering in its gigantism much as our imaginations find themselves reeling in the attempt to comprehend the concept of the infinite or what is tantamount to the infinite space in which the universes are suspended.

It is necessary to grasp the full significance of the foregoing statements in order that one may in turn appreciate the rôle played by the chemical elements in the life and growth of organisms as limited in this paper to the field of the higher green plants only. But before I address myself to a discussion of the subject of this paper directly, it is well to emphasize again what I have said in the foregoing paragraphs by applying the same concepts to the question of the structure and function of plant substance. If the arrangement of atoms of the same kind in a molecule is so strik-

ing a determinant of the properties of the substance thus constituted, if arrangements of two or more different kinds of atoms multiply and diversify enormously the possibilities for such striking results, it is not difficult for the imagination to conceive how the arrangement of the atoms in the very complicated and diversified substances of plant protoplasm may become the chief determinant of the properties of that protoplasm whose properties are but the algebraic sum of the properties of its constituents. It must follow from the foregoing that every type of living cell in order that it may continue to live and grow must be supplied with a certain number of different chemical elements which must contribute to such arrangements or patterns with one another as will determine the production of the substances without whose existence the cell can not carry on the work characteristic of it inclusive of the tasks of repairing waste and of growing.

For such purposes as those described above it is not only possible, but we have some evidence that certain plant organisms may require chemical elements with which other plant organisms can dispense, but it seems beyond a peradventure true that all higher green plants require in common certain chemical elements as an absolute condition of life and growth. Until very recently and for about three quarters of a century or more the scientific world has believed that these elemental chemical requirements common to higher green plants were limited to ten of the chemical elements as follows: oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, calcium, magnesium, potassium, iron. Several years ago Mazé, at the Pasteur Institute in Paris, published experiments which seemed to cast serious doubt on the concept of the adequacy of the aforementioned chemical elements to the life and welfare of plants. By growing plants under controlled conditions respecting purity of chemicals and water used in culture solutions Mazé was able to show that plants can not live or maintain a normal appearance with only the ten elements named supplied to them in adequate quantity. By addition to the culture solution which constituted the medium of plant roots in his experiments, of such elements as boron, zinc, manganese and others besides the elements known to be essential he succeeded in making plants grow normally whereas they would not do so in the absence of such elements. He pointed out that only small quantities of such elements were required by plants but that such small quantities were absolutely essential. The botanical world as a whole regarded Mazé's experiments with much skepticism, however, and further work was necessary to convince plant physiologists of the truth and cogency of his conclusions. In 1922 McHargue furnished results of extensive experiments carried on in both sand cultures and solutions which left no doubt whatever that manganese is an essential chemical element to the growth of many if not all of the higher green plants. He made it clear that manganese is required in such small quantities relatively to other chemical elements known long ago to be essential that the fact of its essential nature could only be discovered by carefully freeing the root medium of manganese and that even then it was essential to grow the experimental plants well along toward maturity in order to determine if a lack of manganese influences their growth and life. There can be little doubt from the experiments described below that if the root media employed by McHargue had in fact been freed of every trace of manganese the striking effects which he noted would have manifested themselves much earlier. The next series of experiments published, which confirmed the contentions of Mazé, were those published by Miss Warington, of the Rothamsted Experimental Station in

England. In these experiments Miss Warington proved conclusively that the Windsor bean could not grow in a root medium devoid of boron. She regarded it as a special case and did not then see the general bearing of her results on higher plants in general. Nevertheless, the finality of her conclusion respecting the indispensable nature of boron to the Windsor bean is beyond question.

Several years ago Dr. A. L. Sommer, then a graduate student in the author's laboratory, undertook for her doctoral dissertation a study of the question of whether or not the elements aluminum and silicon are essential to the growth of higher plants. While she encountered many difficulties in devising adequate technique for insuring the exclusion of aluminum and silicon from the root medium (the culture solution in which the plants were grown) her published results leave little room for doubt that the essential nature of those two elements for some plants at least is clearly indicated. These results, however, did not partake of the finality characteristic of the results of McHargue and of Warington.

With all this evidence before him the author became convinced that the scientific world lacked the actual facts respecting the number and kinds of chemical elements which are really essential to plants. Realizing, moreover, that faulty technique was responsible for the earlier conclusions he determined upon an extensive program of study for the discovery of as many of the facts in the situation as possible. For the purpose of such a study he was supplied with a grant from the research fund of the University of California and engaged Dr. Sommer as a research assistant to continue the work begun by her on silicon and aluminum and to search for the facts in that regard respecting zinc, copper and other elements.

The results of some of these new experiments were published by Dr. Sommer and the author in detail in *Plant Physiology*. There we demonstrated, as Dr. Sommer has further shown in a paper which she published in *Science*, recently, that both boron and zinc are essential to the life of widely different species of higher plants, thus confirming the conclusions of Mazé and of Miss Warington, but making the latter author's conclusion of wider application. These results were made possible through a refinement of technique which required much patience and perseverance and for which Miss Sommer alone deserves credit. The plants were grown in culture solutions in glass containers of adequate size and form. These culture solutions were prepared with twice distilled water and with chemicals which were specially synthesized for the purpose or carefully recrystallized from chemically pure compounds purchased in the trade. Wherever possible the part of the seed remaining after the young seedling had sprouted was removed therefrom so as to remove as much as possible of the stored supply in the seed of the elements under study. Germination was carried on under great precautions in a medium which precluded absorption of the elements not desired. The cultures were grown in a specially constructed compartment in a greenhouse in which as little dust as possible was permitted to enter. "Soft" glass fruit jars were used in the experiments in which it was desired to exclude boron since that glass contains less boron than the "hard" glass of Pyrex jars. In other cases Pyrex beakers were employed which contained little soluble impurities aside from boron. Wherever possible the cultures were grown to maturity. As controls on the cultures grown without a given element, other cultures were prepared with ordinary chemically pure salts not recrystallized and with pure salts to which the element under test had been added. Realizing that the absence of extremely small quantities of other

elements as yet unstudied but possibly essential might vitiate the results small quantities of several of the elements found in plant ash were added even though their essential nature still remains unestablished.

The results of these experiments showed that in most cases plants can only make meager and that abnormal growth in the absence of zinc or of boron. In other cases fair growth is accomplished for a time but in a few weeks the plants fail in the absence of either one of these two elements, everything else being present in adequate quantity. If in the latter case a small quantity of the missing element is supplied to the cultures the plants recover and grow normally. But in many cases plants make no growth at all in a root medium devoid of either zinc or boron. The next very striking thing to observe is how small a quantity of a certain element makes the difference between life and death in the plants tested. One quarter to one half a part of zinc or of boron per million parts of the solution in which the plant roots grow is frequently enough to insure normal plant growth. The absence of such very small quantities of either of those elements prevents growth. It is of the greatest importance to note, however, that the quantities mentioned are in no sense the absolute requirements of plants for the elements in question. They are merely indicative of the general magnitude of the requirements in such cases. With greater refinement of technique such as preventing the introduction of any dust, the more complete removal of the stored material in the seed, the greater purification of water and chemicals, and lesser solubility of the glass the quantities actually essential of the elements in question might perhaps have to be enlarged. All this does not, however, alter the conclusion that the ordinary technique of culture solution experiments, however fine it may appear, is not always equal to the task of discovering whether or not a certain chemical element is essential to plants, for certain elements may be needed in such small quantities that only the very special technique above described can reveal to us their real status in the life of the plant. It is even possible that still other chemical elements are needed by plants in such extremely small quantities that we shall find ourselves unable to devise adequate technique to discover and prove their indispensable nature. Extremely small quantities of certain chemical elements are adequate and alone equal to performing certain indispensable functions in cell growth, and that leads me to my next point.

The effect of all these experiments is to lead us first to the conclusion that in addition to the ten chemical elements acknowledged to be essential to the higher green plants, manganese, boron, zinc, and probably silicon, aluminum, and copper are to be regarded as essential; and second to the conclusion that it is not unlikely that further research will demonstrate that several other chemical elements are also essential. There is no longer a closed list of chemical elements essential to plant growth even though there may still remain some closed minds with respect to that important point. But when we have admitted all this the most important problem in this field still remains and that is what is the function of these elements in plant cells? Even the difficulties of providing adequate technique for arriving at the foregoing conclusions pale into insignificance compared with the difficulty of devising hypotheses, to say nothing of experimental technique necessary to the solution of this really fundamental problem connected with the physiology of the essential chemical elements. It is one thing to prove that zinc is essential to a plant's life; it is quite another and much more difficult thing to prove why zinc is essential to

that plant's life. Nevertheless, such is the confirmed optimism of him who seeks the truth, the scientist is far from hopeless of solving this fundamental problem too. It should be remembered, however, to appreciate how difficult this problem really is that even in the cases of the chemical elements long known to be essential to plants we are ignorant of the functions which they perform. While it may be a partial answer to this assertion to claim that we know how oxygen, hydrogen, nitrogen, carbon, sulphur and phosphorus function in plants because they help to make up its living tissue, it is an incomplete and unsatisfactory answer at best, and besides we haven't even an inkling of why the other elements in the original group are indispensable, certain guesses to the contrary notwithstanding.

We can none the less see some possibility of formulating hypotheses as bases for further experiments. I may perhaps be pardoned for suggesting some such hypotheses in the case of the newly discovered essential elements, inadequate and crude though they be, with the hope that they will stimulate others to make better hypotheses. It should be understood at the outset that there is little probability that any proposed hypothesis or suggested experimental procedure will have cogency in the case of every essential element. It is not to be expected that zinc plays the same rôle in cell metabolism which is played by boron for example. The same conception applies to the elements which are needed by plants in much larger quantities such as potassium and magnesium, and which I am leaving out of consideration in this closing part of my paper. Harking back to the introductory part of this paper the reader is reminded of the emphasis I have placed on the importance of the position and the kind of atom in the molecule as determining the latter's properties. Now if, for example, an atom of zinc is placed in a certain position in a molecule of some complex proteid or even some less complicated organic compound characteristic of the protoplasm it may yield a substance of certain properties without which certain organs of the cell can not function. In the absence of zinc such a substance could not be formed and the cell would cease functioning and die. While zinc is required by plants in very small quantities only such small quantities could easily be equal to the task of furnishing one or more molecules of zinc to enormous numbers of cells and thus provide the latter with all of that element which they require.

The foregoing hypothesis with respect to the manner in which zinc may function may perhaps also be applied to other elements needed in small quantities by plants, but not necessarily. However that may be I can see in it certain elements of validity when I recall the interesting mechanism of cell division and particularly the part played therein by the nucleus, its constituent chromosomes and their hypothetically constituent genes. Geneticists have produced strong, almost indisputable, evidence of the manner in which characters are carried in the genes of the chromosomes. Since, however, the genes carry certain definite units which in turn contain the elements of one or more traits of the organism to which they belong is it not possible that the nature of the traits thus borne by the genes is influenced by the chemical structure qualitative and quantitative of certain substances which they contain? If this is so and any chemical element necessary thereto is missing the whole structure must disintegrate. But if that happens the cells must die. There is some evidence published by Warington and by Warington and Brenchley which seems remotely to lend color to such a hypothesis inasmuch as they found that in the absence of boron the structure of meristematic tissues disintegrates and particularly in

the region of elongation immediately behind the meristematic cells.

It has occurred to me also, as it has occurred to others, that some of these newly discovered elements might be necessary to the normal functioning of one or more of the universally occurring, numerous, and diverse enzymes of plant cells. For this purpose we may use the term enzyme in a very general comprehensive sense to include the so-called catalysts. Much is known about how the enzyme catalase functions in relation to oxygen in living cells, and similarly much is known about the function of diastase in relation to starch and sugar and so forth through the long list of enzymes. But we know nothing of the constitution of these enzymes nor do we know much about the elemental chemical requirements which condition their useful functioning. The imagination readily suggests an indispensable place for such elements as boron in the functioning of some if not all of the enzymes upon the efficiency of which the cell's own integrity may rest. Moreover, we know that in purely inorganic systems certain chemical elements may speed up a chemical reaction enormously by their presence without becoming part of the products of the reaction. We call such substances catalysts and regard them popularly as inorganic enzymes. For example, it is well known that the oxidation of sulphur dioxide into sulphur trioxide may be markedly hastened by the presence of the element platinum in a certain fine state of division, but platinum is not a constituent of sulphur trioxide, the product of the reaction. And yet we know little of the mechanism by which platinum or similar catalysts hasten the reaction in which they are found to function. Is it not possible in view of the great complexity and mobility of the reactions in plant cells that such elements as zinc and copper may be responsible for making possible certain fundamental catalytic reactions in the synthesis of plant substance without which cells can not live or function?

I have suggested only a few of the many possible hypotheses and proposals which the imagination conjures up in meditating on the fascinating problem of the chemical elements essential to plant life. Whatever should prove to be the true explanation for this remarkable potency manifested by infinitesimally small quantities of some of the chemical elements in plant life, it is certain that the fact of the indispensable nature of some chemical elements hitherto considered as unessential constitutes one of the most striking evidences of the overwhelming importance which so frequently attaches to the infinitesimally small in our world. This can never cease to be a source of wonder and fascination to the reflective mind. Moreover, it teaches us, as we have been taught again and again in the past, that great apparent refinement of experimental procedure may always be subject to greater refinement and that that may in turn result in new and important discoveries.

ORIGIN OF OUR PRESENT MATHEMATICS

By PROFESSOR G. A. MILLER
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MORE than half of the mathematics of to-day has been developed since the beginning of the nineteenth century. These developments include a considerable part, but less than half, of what is commonly known as elementary mathematics. To emphasize the modernness of some of our present elementary mathematics it may be noted here that the history of the simplest methods now known for constructing geometrically the roots of a quadratic equation, even when these roots are imaginary, extends into the year 1925. In a general way it may be said that the mathematics of to-day represents largely a survival of the simplest methods to prove certain desirable results. In other words, it exhibits mainly the most economical known methods to secure desired intellectual penetration. At any rate, this is what the mathematician thinks he sees in his work.

This general principle of the development of the mathematics of the present time exhibits clearly one of the greatest difficulties encountered by students of the history of our subject, since such a student usually deals largely with antiquated and unnecessarily difficult methods. It is obviously desirable that the heaps of discarded methods which have been left behind during the development of our subject should be reexamined from time to time to see whether in the light of later advances certain of these discards may be worth preserving, but the mathematical world can well afford to forget some of the mistakes of the past, and a history of our subject, which is largely based on fruitless work, is of questionable value as a history. It should, however, not be inferred that the mathematical historian necessarily deals largely with discarded methods and with fruitless efforts. One of the characteristics of mathematics is that some of our present methods were perfected very early and seem to be permanently useful.

The motives which led to the early development of mathematics are probably of greater interest to the average educated man than an accurate account of the nature of these developments. Hence it may be desirable to note here that Plato regarded the ignorance in his day with respect to solid geometry as laughable and disgraceful, and added that this ignorance would be more becoming to hogs than to human beings and that on account of this ignorance he was ashamed not only of himself but of all the Greeks. This sounds the keynote of the motives which led the ancient Greeks to make such remarkable progress in mathematics. They were interested mainly in securing intellectual insight and realized that such insight reflected great glory on their race as well as on the individuals who first secured it. Unquestionably, there were many other motives which contributed towards the early development of our subject. Some of these were utilitarian, but mathematics, like other sciences, seems to owe most of its progress to the desire to know the facts and the willingness to be guided by them.

In recent years a number of discoveries have been made as regards the mathematical attainments of the Maya of Central America and Southern Mexico. In particular, it has been noted that they employed a positional arithmetic with a symbol for zero, at least in so far as using it as a notational sym-

bol but not as a number. It is, however, unlikely that this development of mathematics had any influence whatsoever on the later advances along this line elsewhere. There is obviously a marked difference between the importance of such work and that of similar work done elsewhere which served as a stepping-stone for further progress. The latter is an essential element in the study of the origin of the mathematics of the present time, while the former is non-essential in such a study. This explains why it has been said that the work of the Chinese may be entirely neglected by those who study the development of our present mathematics. No single instance in which the work of the Chinese has affected this development is now definitely known to exist, notwithstanding the large amount of space devoted to the Chinese in some of the histories of our subject.

In studying the origin of our present mathematics it is therefore unnecessary to study all the known ancient mathematical systems, even if these systems may be of great interest in themselves. In fact, the literature relating to these various systems has grown so rapidly in recent years that it is almost impossible for one man to keep in close touch with all of it. The work of the student of the history of our subject is simplified by the fact that the ancient Greeks so greatly excelled other ancient peoples along mathematical lines that later generations were influenced mainly by their work and neglected sometimes for a long period of time even superior work of other nations along particular lines. For instance, the Arabs did not adopt some of the algebraic advances, including the use of negative numbers, made earlier by the Hindus, and hence the mathematics of the Hindus need not receive much attention on the part of those who desire to trace our present mathematics to its origin. It is becoming more and more clear that the mathematical developments of the Hindus and of the Chinese were largely influenced by those of the Greeks.

It has often been assumed that our present number symbols are due to the Hindus. This is so far from being established at present that a recent student of this question makes the following statement: "It may now be regarded as proved by Bubnov that our present numbers are derived from Greek sources through the so-called Boethian 'apices,' which are first found in late tenth century manuscripts. That they were not derived directly from the Arabic seems certain from the different shapes of some of the numerals, especially the 0, which stands for 5 in Arabic."[1] Hence those who desire to get as close to the origin of our common numerals as they can authentically at the present time do not need to study the various number symbols of ancient India for this purpose. The common term "Hindu-Arabic numerals" is therefore not strictly in accord with present authentic knowledge along this line.

Figuratively speaking, it may be said that the ancient Greeks constructed the earliest known mathematical ladders for the purpose of reaching the higher fruit on the mathematical tree. The earlier races picked only such fruit as they could reach from the ground. The advantages to be derived from the use of these ladders were recognized by all the later races which made serious mathematical progress, but for many centuries after these ladders were first constructed the mathematical appreciation of the world was slight and many of the mathematical advances, even some of those made by the Greeks themselves, were forgotten. In particular, what was achieved in Alexandria from the close of the third to the sixth century of our era has been practically lost except in so far as this work may possibly have influ-

[1] Robert Steele, "The Earliest Arithmetic in English," 1922, p. xvi.

enced the Hindus and the Arabs, and may thus reduce still more the credit now usually given these peoples for having made original mathematical advances.

Although the Greeks are preeminently the people of mathematical history to whom the adage "to him that hath shall be given" applies, it is probable that even they were the originators of considerable work for which others are now given credit. It is possible, in particular, that their algebra was developed considerably beyond what may be inferred from the part of the work of Diophantus, which has come down to us, and that they may have used explicitly the sine function in trigonometry at an earlier date than the Hindus. On the other hand, it seems well established that many valuable trigonometric tables were computed by Arabian scholars but did not become known in Europe until after similar tables had been computed and published by Europeans. The student of the history of our present mathematics may reasonably be less interested in what progress various nations may have made along mathematical lines than in the question of the effect, if any, that the work of these nations may have had on the development of our present mathematics.

A fundamental fact which is clearly illustrated by the development of our present mathematics is that while reading is a good thought stimulus it, like some other stimulants, constitutes by itself a pernicious intellectual diet. Mathematicians wisely recognized the superiority of the work done by the Greeks in comparison with work done by other ancient peoples along similar lines, and hence they properly studied the former work very carefully. For many centuries they failed, however, to lay sufficient stress on the great shortcomings of this work and the great barriers to further progress created by these shortcomings. Among these shortcomings the very limited number systems of the Greeks are most conspicuous to the modern student of elementary mathematics. One of the most harrowing experiences of the human race has probably always been the burden of debts, and one might think that some of the advantages of the use of negative numbers would have been so forcibly suggested thereby, as well as by many other experiences, as to lead to an early introduction and a wide use of these numbers.

This was, however, not the case. The ancient Greek number systems were signless. In this respect the Greeks seemed to have been unanimous while they were not as unanimous in saying that *one* is not a number, as is often assumed. Naturally most of the enthusiastic admirers of the ancient Greeks for many centuries adopted their mathematical faults as well as their mathematical virtues, and we find even in the eighteenth century European mathematicians of considerable note who contended that negative numbers should not be used on account of the logical difficulties which they present. In the seventeenth century, as noted a mathematician as Thomas Harriot thought he had proved that an algebraic equation could not have negative roots. It was not until about the beginning of the nineteenth century that the legitimacy of the use of negative numbers in mathematical operations was fully established, notwithstanding the fact that the great usefulness of these numbers in such subjects as trigonometry and analytic geometry had become apparent at a considerably earlier date.

The preceding reference to the introduction of negative numbers may serve to suggest the fundamental rôle of formalism in the development of the mathematics of to-day. It was not until after it was established that negative numbers obey the formal operational laws of algebra that these numbers were fully accepted. Steps towards the establishment

of this fact may be found in the work of various Greek writers. For instance, Euclid knew that $(a-b)^2 = a^2 - 2ab + b^2$, although he did not express his result in this formal manner. The fact that the product of two subtracted numbers becomes an added number, provided the positive subtrahend exceeds the positive minuend, was not only clearly exhibited in the work of Diophantus but was explicitly expressed in this work. The slowness of the introduction of negative numbers under such formal influences as the close approaches to these numbers in widely known Greek works and their very apparent usefulness presents a clear illustration of the intellectual attitude during many centuries preceding the beginning of the nineteenth.

The great importance of formalism in the development of mathematics may be illustrated by the wide difference between the use of the equation in chemistry and in mathematics. In the former subject the equation serves to express in a clear way what is already known, while in the latter the algebraic equation of degree n involves not only the unknown which has been explicitly put into it but also $n-1$ others, and hence it serves to extend the field of research and becomes itself an object of study. Here again the ancient Greeks failed to make a very good beginning, since they were satisfied with one root of the quadratic equations which they considered. In fact, it was not until the seventeenth century that it was definitely assumed that every quadratic equation has at least one root and it took almost two centuries more to secure a clear insight into the nature of the numbers by means of which such equations can always be solved. If our modern students can now master such matters with very slight effort, as we usually assume they can, mathematicians have succeeded marvelously in their efforts to simplify matters, and the view expressed at the close of the first paragraph is at least partly justified.

SOME PHILOSOPHICAL ASPECTS OF RECENT ATOMIC THEORY

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THE problem of the constitution of matter goes back to remote antiquity for its inception. Through almost all the ages it has excited the keen interest of thoughtful men, and to-day its solution has become the principal goal of modern physical science. Beginning as a philosophical problem to be attacked by meditation solely, it is now being worked upon by the combined resources of both experimental and theoretical physics. Whether the philosophers, as a class, may be said to be still interested in it is doubtful. During the passage of the years their attention has been diverted to other problems, and the unraveling of the twisted, hidden thread of the structure of matter has become pre-eminently the task of science.

And yet when we consider that the early philosophers founded the atomic theory and that it is just this theory which forms the threshold of our modern attempts at a consistent theory of matter, it seems a pity that physical science and philosophy are so widely aloof in this interesting period of the development of knowledge. The rise of the atomic theory in physics and chemistry has been concomitant with a general shifting of major philosophical interest to other fields than ontology and epistemology, namely, to ethics, religion and more recently to psychology. It is doubtless this fact which has led most educated people (I mean educated laymen, not themselves scientists) to believe that the problem of atomic structure is solely one for science to concern itself with; and indeed one often hears the *vague speculations* of philosophy contrasted to the *solid* facts of physical science. What with the popularizers' glib and facile talk about protons and electrons, stationary states and quantum jumps the poor layman is apt to acquire the impression that modern atomistics has completely arrived! And I fear that some of us in the scientific fold are not a little responsible for this state of affairs. There is no doubt that the reality of the atom and its structure is fast becoming an article of holy faith among physicists generally in spite of the incomplete nature of our modern theories, an incompleteness which is but too manifest to those working most closely with the subject.

For this reason it seems to me to be time to re-emphasize the place of metaphysics in atomic theory, lest it be forgotten that there is an important philosophical element in all this development. It is a truism that no science can advance far without the aid of a metaphysical element. This bald statement may cause horror to many experimentalists, but by it I am merely emphasizing that the successful development of any science is absolutely dependent on the manufacture of hypotheses and that the state of progress to which the particular science has attained is due largely to the character of the postulates on which it has been built. Nowhere has this been more conspicuously evident than in the rise of atomic theory in the physical sense. It was the bold guesses of Prout and Dalton which gave so much stimulus to the advancement of chemical knowledge that they practically founded modern chemistry; while the revolution-

ary assumptions of Planck, Rutherford and Bohr are directly at the basis of the enormous mass of investigation into the constitution of matter which we have witnessed during the past two decades. It is true that physics, like all science, rests on experimentally determined facts, but it stagnates without the spur of hypothesis, of a theory to guide the seeking out of the facts and to accomplish the correlation of the new with the old. In its choice of what I choose to call a *metaphysics* (in the sense of something beyond the observed facts of physics) it finds its success or failure. By a successful physical theory we thus mean a postulate or group of postulates relatively simple and few in number involving quantities which may themselves not be observable or measurable and yielding on analysis relations which are consistently satisfied by the observed data over a wide range of physical phenomena. Naturally the greater the range of phenomena which can be consistently correlated with respect to the group of hypotheses, the more satisfactory the theory; likewise the greater the number of avenues of experimental research opened up by the hypotheses the more successful is the theory. A complete analysis of what constitutes a successful physical theory need not detain us here. Vivid sidelights on the many phases of this question are to be found in the work of Poincaré, which every student of physics should read and ponder. But what I am trying to emphasize here is the philosophical element that we should never forget.

Lord Kelvin spent a good part of his later life elaborating and working on the elastic solid theory of light. That work can not be considered without value, and yet we must recognize that his hypothesis has not been a fruitful one in the light of events, as judged by the standards just set forth. On the other hand, the electromagnetic theory, with all its difficulties, *has* been what we may call a success. The advance of physics is full of like examples, and they all indicate the extreme importance of the choice of hypotheses.

In this connection there often arises an interesting psychological difficulty. It is this: having once chosen a hypothesis or group of them on which to base the development of a physical theory like that of atomic structure one may, often almost imperceptibly, fall into the state of looking upon the system chosen as the only true reality. It is then that the discovery of some new phenomenon not easily explainable in terms of the original hypothesis injects temporary confusion into the science. Of this there are numerous illustrations in the development of physics. One commonly cited nowadays concerns the difficulties over matter in motion which arose from the use of the older metaphysics of absolute space and absolute time. From the standpoint of the present article, however, a still more illuminating example is to be found in the woeful mix-up in our present ideas on the emission and propagation of radiant energy, a problem very closely bound up with that of atomic structure. The researches of the last century based on the hypothesis of the undulatory nature of light were so successful and led to the creation of such a well-established, consistent body of knowledge that it was hard to doubt the reality of it all—this was gradually taken for granted, I think, by most physicists. It was for this reason that the discovery of the discontinuous nature of the emission of light has proved so disconcerting; for we are here dealing with phenomena which in no simple way have been subsumed under the wave theory, in spite of the many attempts that have been made to do so. The warning provided by this example is very plain: we must never be too ready to attribute complete reality to any one hypothesis no matter how satisfactorily it may appear to correlate known facts.

There is always the chance that it may break down in a crucial experiment.

We must grant, of course, that it is the ultimate aim of physics to unify all our knowledge of the physical world in as small a number of generalizations as possible. Yet it is a moot question as to how much is gained by trying to force new facts to fit an old hypothesis. The comparative experience of the late nineteenth and early twentieth centuries would indicate that the physicist who is unwilling to consider entirely new and in themselves not completely understandable concepts will not get very far. Patching postulates may allow us to correlate a large amount of data, but in the long run it violates the well-known criterion of Mach, as well as the famous razor of William of Occam. The point I am trying to lead up to is just this: that there are often occasions when it is not only necessary but desirable to tolerate a *dual* representation of phenomena. This is exactly what we now have in the theory of radiation. As long as we are talking about the *propagation* of light the wave hypothesis is an extremely satisfactory one. On the other hand, the quantum theory, the fundamental concept of which is so difficult for our minds to absorb since it breaks so completely with previous notions, accounts with comparative ease for all hitherto discovered phenomena connected with the *emission* of light. This constitutes a dual representation and is apparently causing many physicists much sorrow and dissatisfaction. It is also possible that knowledge of this situation has led many laymen to feel that modern physics is after all only mental ping-pong. This is unfortunate, for the dual nature of our modern view of light is nothing to be ashamed of. On the contrary it is proving a wonderful stimulus to research.

Moreover, looking at the matter of the dual representation in a somewhat different light, I think there is a sense in which we may be justified in considering both concepts, *i.e.*, waves and quanta, mutually consistent. I mean that it is perfectly possible to conceive of the emission of radiant energy in quanta from the individual atoms with the consequent production of waves before the quanta get away from the atoms. That is, in the medium in which the atoms are embedded, we have to think of radiant energy as always in the form of waves, while in the atoms it must always be thought of in terms of quanta. This of course introduces an element of discontinuity, but there should be nothing alarming about that. The very assumption of the existence of the atom itself with its component parts has already brought in discontinuity, and we may very well expect that the concept of discontinuity is to be one of the most fundamental in modern physics. At any rate it is already predominant in the minds of most of us.

In coming to the main problem of the structure of the atom itself, it is not improbable that we have to deal with a dualism closely connected with that involved in light quanta and waves. By that I mean that even if we are willing to accept the picture of an atom as composed of nucleus and electrons there is no *a priori* reason to suppose that these particles behave when together in the atom as they behave as individuals at considerable relative distance from that atom and other atoms, *i.e.*, in what we may call free space. As a matter of fact we know that the "free" electrons in their motion obey the laws of classical mechanics as modified by relativity, while it has so far been impossible to represent the motion of the electrons in the atom (the "bound" electrons) by any consistent application of classical laws. In view of this it has been suggested that the phrases "position of an electron" and "velocity of an electron" have entirely different meaning when applied to the bound electron than they have for

the free electron. This view is inherent in the theory of Heisenberg, the so-called new quantum mechanics. It involves a dual representation which here again seems to be meeting with success. Even on the older Bohr theory we have dualism with the postulation of the discrete stationary states, only here there was a concession to our traditional mechanical concepts in the assumption of motion of the electrons in actual orbits determined by the laws of classical dynamics. For the simple case of hydrogen (one electron) and hydrogen-like atoms this theory has worked very well, but already in the helium atom with two electrons the problem has not yielded results at all in accord with the observed data. The conclusion is patent that the dualism of the early Bohr theory was not sufficiently thoroughgoing. The newer theory discards electron orbits and focuses attention on the atom as a whole which can exist only in certain discrete stationary states. The atom is then represented as an aggregate of virtual linear oscillators with frequencies corresponding to all possible transitions of the atom from one stationary state to another. Such an aggregate is of course a doubly infinite matrix and hence the name "matrix mechanics" which has been applied to Heisenberg's theory.

This theory has many interesting philosophical aspects. For the moment let us consider a suggestive question which has arisen in connection with the development of the new mechanics. We may phrase it in this way: Is it after all really possible to build a completely consistent theory of atomic structure in terms of our ordinary conceptions of space and time? To give a precise answer to this question would demand a more detailed analysis than I wish to enter upon here, but there are a few points which are worth mentioning. If by the kind of theory stated in the question we mean one in which we are allowed to use freely the classical electrodynamic concepts of position, orbit, velocity and acceleration, then the weight of the evidence so far is definitely negative. As has already been emphasized above, it would have been very remarkable and almost too good if concepts in terms of which we can successfully describe the motions and behavior of free electrons and α-particles were found capable of dealing with these same particles when close together in the atom. On the other hand, we must consider the possibility of extending the meaning of the terms so that the phrase "position of an electron" inside the atom has a definite significance closely related to that attached to it on our usual conceptions, and similarly for the others. No one would be willing to deny that a *consistent* theory could be erected on such concepts, and it might work. For example, it may very well be meaningless to say that at a certain definite instant of time an electron is at a certain point with reference to the nucleus and the other electrons in the atom. It may prove more desirable, if we are to speak of the distribution of electrons in the atom at all, to say that by position of an electron we mean simply an average space distribution of negative electricity about the nucleus. As a matter of fact it has been by an assumption of this nature that the Bohr theory has been able to account in *approximate* fashion for the structure of atoms with several electrons. Of course one may say that this amounts practically to discarding entirely the concept of electron position and this is true if we interpret the word "position" in its ordinary sense.

This in turn suggests the interesting consideration: Even if we find it necessary in order to build a consistent successful theory to introduce concepts which differ from our usual ones, will it or will it not be desirable to translate the results into the old terminology and talk, for example, of electrons revolving

in orbits, etc.? That is, will we ever be willing to abandon utterly the atomic model in terms of electrons and nucleus? If we follow the tendency set by the newer theories we must certainly do so. For it is one of the principal postulates of the matrix mechanics that the theory should concern itself simply with the *measured* quantities in the atom, namely, the frequency of the emitted radiation, its intensity and polarization, and the energy radiated. Carried to its logical conclusion it forbids us to have anything to say about electrons at all. But I venture to believe that most modern physicists are not going to remain greatly satisfied with a theory of that kind, no matter how consistent or even successful it may be. They will doubtless insist on translating the results into the terminology of a mechanical model. This is due to the unescapable psychological bias which makes us say that we can "understand" a theory in which an actually conceived particle like an electron moves in a definite way and so gives rise to other phenomena. And so it appears likely that the atomic model will still flourish as long as the "old familiar notions" still hold sway. It is another question and somewhat out of our province here whether we shall in time become sufficiently familiar with the purely quantum concepts of energy and frequency in themselves alone, to be willing to forego the space and time scaffolding into which we now must place them. It might be remarked on this point that there has been in fact a gradual growth of familiarity on the part of physicists with concepts which began by being extremely recondite. The notion of the electromagnetic field is an illustration.

It is probably rather early to discuss from a philosophical viewpoint the still more recent theory of Schrödinger in which the motion of the electron is replaced by that of a wave, which, however, is not the radiant energy wave but only a phase wave with a frequency proportional to the energy of the atom. Here we are again getting away from the pictorial viewpoint in the replacement of a discrete particle moving in a definite orbit by the distribution and propagation of a certain undefined function throughout space. As a mathematical formalism the theory has proved itself of great value in the handling of many atomic problems, but for the reasons amply outlined above, it is unlikely that the descriptive content which Schrödinger has tried to put into it will appeal to many physicists, who once again will seek to translate its results into the familiar picture.

It must be remembered, and this is an extremely important point, that in no one of the more recent theories is there any attempt seriously to account for the fundamental quantum relation, $E'' - E' = h\nu$; that is, that when the atom changes from one stationary state with energy E'' to another stationary state with smaller energy E', there is radiation emitted of frequency $\nu = \frac{E'' - E'}{h}$, wherein h is Planck's constant. It is allowable to believe that the whole mystery of atomic structure lies in this simple formula, and our attitude toward the whole problem is more or less clarified by the attitude we take toward this relation. There are two courses to pursue. We can first look upon the relation as really fundamental in the sense that it is inexplicable in terms of anything else. It simply expresses the quantum concept which seems necessary for the description of all small scale processes in which single atoms are concerned. From a philosophical point of view it is, of course, natural to expect that a law governing the behavior of a discontinuous entity like the atom should be expressed in the form of a *difference equation* rather than in the form of a *differential equation*. But as to the exact nature of this difference equation we

know *a priori* absolutely nothing. And the actual equation which we are forced to use has no meaning in classical electrodynamics if we give to energy and frequency their usual significance. This offers an outlook on our second course. It is conceivable that by associating *new* meaning with the old concepts or at any rate subjecting them to new conditions we may make the classical relationship take the quantum form. For example, we ordinarily think of the frequency of any periodic wave propagation as a *constant* quantity dependent only on the source of the disturbance and independent of the medium. Now it might be that this is not true of the state of affairs inside the atom. Thus there might be a progressive change in frequency inside the atom, such that in a transition from one state to another, although the electrons or whatever entities do jump may make oscillations of varying mechanical frequency, these frequencies would all be changed into one radiation frequency before the radiation left the atom.

It is evident that there is a great deal of room for ingenuity in making artifices to fit the quantum transition equation into our classical ideas. These hypotheses will have to be judged by their fruits and at present no one of them seems to be of sufficient value to be pursued very far. The relation under consideration has appeared in so many phases of atomic phenomena and has been instrumental in bringing so much order into what would otherwise be wholly chaotic material that we surely can not discard it altogether. And in retaining it, it is probably better for the present to view it as a fundamental postulate on which to build any theory of atomic behavior which seems best able to fit the facts.

This is not the place to consider in too great detail the problem of what takes place inside the atom, but it may be worth while to reiterate that in the broad sense the attack on the problem may be made from two philosophically quite different points of view. If we adopt the first we seek to create a *picture* involving conceivable motions of some entity or entities in space and time. These entities need not be electrons or particles of any kind. For example, they might include continuous material media which could move subject to certain boundary conditions. In this connection it may be worth while to recall the fact that as far back as 1903 Ritz succeeded in devising a two-dimensional bounded continuum whose oscillations have natural frequencies obeying the Balmer law. It might be possible to attach a physical significance to the particular continuum chosen; the only drawback to it being its extremely complicated nature. Simplicity must be considered one of the essential features of any successful picture and it is for this reason that the Bohr theory has proved so alluring, yet its very simplicity has involved it in such serious difficulties that no one doubts that it must be materially modified. This modification may still retain the "picture" point of view, or it may, as in the matrix mechanics or in the more recent wave mechanics, discard completely the attempt to make a picture of atomic processes and content itself merely with the formulation of certain mathematical relations which yield the proper values for the measured quantities. It may be well, however, to re-emphasize here the doubt (already expressed above) that this method of attack will ever satisfy physicists in general.

From what has been said it will be clear, I think, that the modern atomic physicist is becoming more and more of a philosopher. This does not mean that he is losing touch with facts, but rather that he is coming more and more to realize that the data of atomic physics are so extremely complicated that without philosophical interpretation, *i.e.*, the

introduction of new and satisfactory hypotheses, they are meaningless. And we have seen that the choice of hypothesis, that is, the character of the physicist's philosophy, determines to a large extent his success in interpreting the facts at his disposal. This attitude on the part of the physicist, which after all is not new but is only becoming more and more emphasized, is bound to have some influence on the development of philosophic thought in general.

Thoughtful physicists have for a long time affirmed quite strongly that the question of the reality of the external world has no meaning for them. For they have conceived their task to be solely the analysis of a certain group of our sense impressions; behind these they have not desired to go. Yet with the increasing complication of modern physics, particularly in the atomic realm, there has arisen this peculiar and somewhat paradoxical situation: having *created* the atom and its constituent parts to account for a vast mass of indubitably valid phenomena, physicists are coming to believe in the intrinsic *reality* of their creation. That is, it is real to them in the sense that when they hear of any new phenomenon, the chances are that after pondering they will remark, "Oh yes, that is because the protons and electrons go so and so!" It is just as hard to convince the physicist who has performed experiments in radioactivity, X-rays or cathode rays of the unreality of electrons as it is to convince the average person of the unreality of the stone on which he stubs his toe. The physicist, therefore, unconsciously perhaps but nevertheless quite inevitably takes up a rather definite view as to the nature of the external world, in his insistence that the protons and electrons of the atom are its building stones and primordial elements. We must not blame him for this, for it is a thing he can not help. Yet what it means is this: that the ideal —the creation of the mind—is in this case for all practical purposes identical with the real. In modern physics the strongly contrasted philosophical doctrines of realism and idealism merge into a common pragmatism. We build a hypothesis which seems best to satisfy our longings for logical completeness and then we act toward our hypothesis as if it were reality, because it works. This is a very sensible attitude, yet, as has been pointed out earlier in this article, we must never forget that this reality is of necessity a transient one. New facts render old hypotheses untenable—the old reality yields to new reality and so science progresses. More and more it becomes clear that the true reality is but the ideal with which we have become so familiar as to believe in it and have faith in it.

There may be a question as to the influence on the development of philosophic thought itself of such considerations as we have presented above. But it seems to me that as far as ontology and epistemology are concerned, mo... philosophers are realizing that the way to progress lies in a greater attention to the data of science. After all in that direction lies our only *sure* prospect of knowledge. Certainly it seems that a searching examination of the concepts which lie at the foundations of scientific theories would provide more useful problems for philosophical attack than the construction of philosophic systems which have little connection with the data of our sense perceptions. That this is already being realized is clear from an examination of the works of Russell, Whitehead and others. It is to be hoped that this movement will continue with increasing vigor. For if the philosophers do not press forward in this direction the scientists and particularly the physicists must.

PHARAOH'S DOCTOR

By ANTHONY J. LORENZ

THE line between the medical quack and the scientific surgeon was clearly marked at the very dawn of man's intelligence.

When primitive man had an attack of indigestion he blamed it on a host of demons.

When his skull was bruised in combat and he suffered a headache, he was more practical. He was able to understand the relation between his enemy's club and his physical hurt. He recognized the outside force causing his head to ache, but was unable to diagnose his internal ailment.

This is clearly shown in the publication of the first English translation of the Edwin Smith "Medical Papyrus"—the oldest scientific book in the world. The translation has just been completed by Professor James Henry Breasted, of the Oriental Institute of the University of Chicago, and is being printed for the New York Historical Society, the owner of the manuscript, by the Oxford University Press, which at present has the only facilities for setting up the ancient hieroglyphs in type.

This document, says Professor Breasted, is of unique interest not only to the Egyptologist and anthropologist in showing the awakening of man's reasoning powers regarding disease but of extreme importance to the history of medicine. The Edwin Smith Papyrus, a roll some fifteen feet in length, dates from the late seventeenth century B. C. and is regarded as the most important document in the history of all science surviving from the pre-Greek age of mankind. Its seventeen columns contain a portion of an ancient treatise on surgery and external medicine which began its discussion at the top of the head and, passing downward, presumably continued to the soles of the feet.

Unfortunately, the ancient scribe failed to copy further down than the thorax and the beginning of the spine the surgeon's observations of human hurts. The papyrus, however, contains so much information regarding the really remarkable knowledge which the author-surgeon of 4,000 years ago had that some of his diagnoses and treatment methods when shorn of their curious phraseology are surprisingly modern.

He had quite a complete knowledge of the human anatomy far in advance of medical scholars even of the middle ages; he felt that the heart and brain played important rôles in our physical make-up; he knew something of the pulse or pulsation and of the circulatory system.

In its text and glosses the human brain appears for the first time in medical literature. Its author knew that the folds of the brain lie in convolutions. His description of them is perhaps even more graphic than a modern physician might employ. He says they are "like those corrugations which form on molten copper" and in taking up this vivid comparison in a gloss he explains that the reference is to the floating slag forming on molten copper which the coppersmith rejects before he pours the metal into the mould.

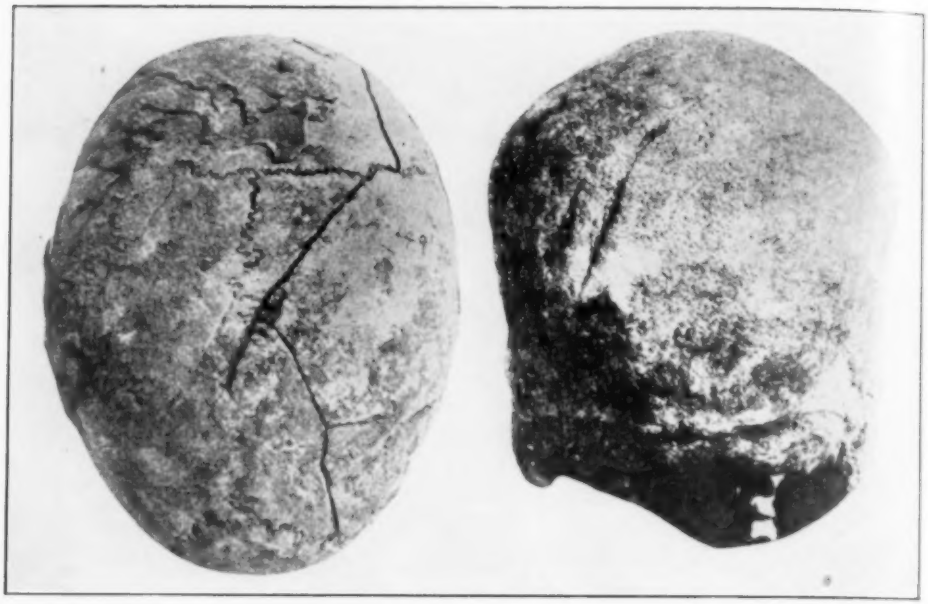
"Any one who has observed these convolutions into which the metallic slag forms itself will recognize the aptness of the ancient comparison," says Professor Breasted in his commentaries on the text.

In still another gloss is explained

THE OLDE

A PAGE OF THE EDWIN SMITH PAPYRUS

THE OLDEST MEDICAL BOOK IN THE WORLD, DATING BACK TO THE SEVENTEENTH CENTURY B. C.



EGYPTIAN SKULLS

(LEFT) SHOWING SWORD CUTS WHICH MUST HAVE PROVED IMMEDIATELY FATAL AND WHICH THE ANCIENT EGYPTIAN SURGEON, AUTHOR OF THE SMITH PAPYRUS, WOULD HAVE DISMISSED WITH HIS "VERDICT NO. 3—A CASE I WILL NOT TREAT."

(RIGHT) THOUGH ITS OWNER SUFFERED A SEVERE SWORD CUT, THE SKULL DISCLOSES EVIDENCES TO THE MEDICAL EXAMINER OF HAVING BEEN TREATED ALONG THE SURGICAL LINES LAID DOWN BY THE AUTHOR OF THE SMITH PAPYRUS. THE PATIENT SURVIVED, ACCORDING TO G. ELLIOT SMITH AND F. WOOD JONES, BRITISH ARCHEOLOGISTS, WHO STUDIED THE EFFECTS OF ANCIENT SURGICAL PRACTICES ON HUNDREDS OF MUMMIES.

that "when rending open the brain" in a compound comminuted fracture of the skull "the membrane or skin enveloping the brain which is rent breaks open his fluid in the interior of his head."

This, said Professor Breasted, is the earliest known reference in medical history to the meningeal membrane.

Again, this old papyrus makes the earliest observation showing that the brain is the center of nervous control. The Egyptian surgeon in his practice had noticed that injuries to the skull and brain result in disturbing the normal control of various parts of the body, even as far away as the feet.

The most remarkable observation in his text-book is made in connection with still another case of compound, comminuted fracture of the skull which, however, displays no visible external contusion. Here the surgeon makes the following notes in his picturesque, though strictly scientific, observations:

> His eye is askew because of it, on the side of him having that injury which is in his skull; he walks shuffling with his sole, on the side of him having that injury which is in his skull.

To Professor Breasted the repetition of the word "that injury" suggests that the surgeon is calling attention to the fact of the fact of the effects of an injury in a situation which may be distant from the place of the observed effect.

"Much more remarkable," says Professor Breasted, "is the repetition of the detail 'on the side of him having that

injury which is in his skull,' " showing that the surgeon was aware of the relationship between the side of the brain which has suffered and the side of the body which is affected by the brain injury. The fact that he distinctly specifies in both cases on which side the affected foot and eye are with reference to the injured side of the brain is highly significant, and indicates that he has already discerned the localization of control in the brain.

On the other hand, there is no effort on the part of the ancient writer to correlate these evidences of a nervous system centering in the brain with similar defects arising from injuries of the vertebrae, and he does not attempt to discuss the loss of speech ensuing from the crushing of the cervicle vertebrae case examination.

Professor Breasted adds:

> Indeed, the Edwin Smith Papyrus discloses no word for "nerves" and there is no indication in any of the Egyptian documents that such a designation existed at this remote stage of scientific knowledge of the human body.
>
> The papyrus reveals to us an ancient Egyptian surgeon in contrast with the physician; with the ability to observe, draw conclusions and thus, within the limitations of his age, to maintain a scientific attitude of mind.

Whereas the physician of that day dealt with the majority of human ills as being of a demoniac origin and sought treatment for them in incantations and other magical formulas, the surgeon went about his work scientifically, the papyrus reveals. It differs strikingly from all the other known Egyptian medical books, such as the Papyrus Ebers and the Papyrus Hearst, in that it is not a list of recipes but an orderly arrangement of cases.

Systematically arranged, the material reveals an attitude approaching that of a modern-day scientist. Its cases are very largely injuries, such as sword cuts in the skull, bone fractures and contusions, resulting probably from injuries suffered in erection of those great monuments which gave Egypt the first place in architecture.

As these are due to physical causes quite clear to the surgeon-physician, they obviously had no connection for him with the activities of malignant demons of disease. Injuries, therefore, caused by intelligible physical agencies formed a realm not readily invaded by magical powers—a realm, as Dr. Breasted remarks, "in which the Egyptian physician gathered the observable facts of anatomy, physiology, surgery and therapeutics quite unbiased by his inherited tradition regarding the demoniacal causes of disease, and we have the mind of the ancient Egyptian revealed to us here as interested in the observable facts of science for their own sake."

The ancient author was a frank though cautious doctor with a seemingly high regard for medical ethics, who divided his diagnosis into three groups according to the seriousness of the ailment or injuries he might be asked to treat. He naïvely grouped them as follows:

> 1—An ailment which I will treat.
> 2—An ailment I will contend with.
> 3—An ailment not to be treated.

In sixteen out of the fifty-six physical examinations listed in the papyrus, the surgeon omits all suggestion of treatment. In twelve of the sixteen instances the unfavorable verdict number three is appended.

The author of the papyrus in his arrangement of cases evidently intended to pass from the trifling to the more serious or fatal cases. He begins with slight superficial injuries involving only the overlying soft tissues and then proceeds gradually to more serious injuries affecting the underlying bone.

Thus in the first section of the treatise is the case of a superficial scalp wound. Case number two is a more gaping cut

but, like number one, leaves the bone uninjured. Case number three, however, begins a series of deeper wounds affecting the skull. Case number four a compound fracture of the skull, number five a compound comminuted fracture. Case number six is the same as number five with the addition of a rupture of the meningeal membranes. Cases number seven, eight and nine are similar but fatal injuries to the skull.

Mechanical appliances and processes, on which the ancient surgeon relied, appear for the first time in the literature of medicine in the Smith Papyrus. Among them are lint made from a vegetable tissue and frequently applied both as a vehicle for the medicaments externally used, and as an absorbent of blood secretions. Plugs or swabs of linen, usually in pairs, and bandages made of linen and manufactured for surgical use by embalmers are listed and named as "coverings for physicians' uses." Medicaments applied externally were almost always bandaged on.

Adhesive plaster made of strips of linen, always in pairs, applied transversely "to the two lips of the gaping wound to cause that one join to the other" are called "2'wy of linen." Several references are made to surgical stitching.

"Thou shouldst draw together for him the gash with stitching," one of the passages reads. The word used to designate "stitching," or the verb "to stitch," is "ydr," in contrast to the term for adhesive plaster and stitching, "ndry," meaning "to draw together."

Cauterization is suggested in only one case, in the treatment of an unidentified tumor on the breast, and the instrument employed is called "a fire stick," probably the fire drill used by the Egyptians for kindling fires.

Three different kinds of splints were known to the old surgeon, according to the papyrus.

One defined as a "brace of wood padded with linen," is called a "rnd't of wood," for insertion in the mouth of a patient suffering with constriction of the ligaments controlling the mandible, and according to Dr. Breasted, suggests tetanus or lock-jaw. The surgeon ordered it applied to hold the mouth open and permit feeding with liquid food.

A second kind of splint was ordered for application to two fractures of the humerus and from the description may have been the forerunner of the modern surgical cast.

A stiff roll of linen was ordered as a third kind of splint in the treatment of a fractured nose.

Supports for maintaining a patient upright in bed are prescribed, and from the word used in describing them it would seem that they were made of adobe or sun-dried brick, probably made to fit the body of the patient.

The effective methods of the Egyptian surgeon in the use of such splints is also shown by Dr. G. Elliot Smith's examinations of more than a hundred fractures of the forearm in mummies among which he found only one that had failed to unite.

"In spite of the fact that a certain proportion of the cases of fracture (always due to direct violence) must have been compound," Dr. Smith remarks, that "only one shows any sign of suppuration having occurred."

The surgeon was evidently at a loss regarding the immediate mechanical manipulation of a serious fracture of the skull, but he recognized the importance of quiet, combined with a sitting posture maintained by the adobe piers, of normal diet, but with no binding of the injury and no medicine.

It would seem from the discussion of the case in the papyrus that no direct manipulation of the wound was attempted, and Dr. Smith in his mummy examinations declared that none of the

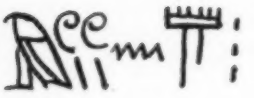
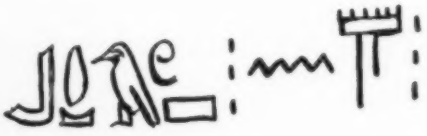
Fig. 1.  "two" ˁ-wry of linen

Fig. 2. ydr (adhesive tape.)

Fig. 3. ndry (to draw together)

Fig. 4.  mdˀt (Splints padded with linen)

surviving bodies "shows any indication that the process of trepanning was practiced by ancient Egyptian surgeons."

"It is an interesting fact," Dr. Breasted remarks, "that in our ancient treatise there is a sharp distinction between such mechanical and surgical manipulations and the treatment with medicaments."

In nearly all cases of injury the surgeon is charged to probe the wound, a process carried out with the fingers in most instances and in some instances "with a swab of linen." Attention is called to the pain which this probing produces: "both his eyebrows are drawn and his face is as if he wept."

A detailed treatment for a dislocated jaw bone, or rather its examination, is given in one instance:

"Thou shouldst put thy thumb upon the ends of the rami of the mandible in the inside of his mouth, and thy two claws (two groups of four fingers) under his chin and thou shouldst cause them to fall back so they rest in their places."

Thus the ancient Egyptian practitioner was inclined to include some things in the examination which a modern surgeon would readily classify as treatment. On the other hand, he includes in the proper treatment the use or application of medicaments and recipes, the characteristic agencies of the physician. He, therefore, placed the operation in the great majority of cases in the examination and reserved for his treatment the use of alleviatory and curative external medicaments, the recipes for which are so abundantly found in all the other medical documents in old Egypt. Here is the sharp distinction between the surgeon, on one hand, and the physician on the other.

In the treatment of a compound comminuted fracture of the frontal bone the surgeon-author has culled the only

magical treatment in his book of surgery and external medicine.

"It is a well known fact," remarks Professor Breasted, "that even in the mind of a modern man otherwise rational and scientific there may be found lurking surprising manifestations of superstitions. Undoubtedly, our surgeon never more than partially escaped the current superstitions of his age, even those which ran counter to his general attitude toward his craft or as in the treatment of the above case, to the rational views which he usually held."

In the therapeutic measures which the surgeon combined with his purely surgical procedures he is for the most part in an archaic age, suggesting so pointedly that his surgery is far in advance of his medicine.

In all the treatable cases he follows up his surgery with medicaments, although they are for the most part primitive in character. His favorite remedy, for instance, was fresh raw meat bound on to the wound on the first day, but no longer, and usually followed by a daily application of lint saturated with oil and honey. One of his remedies has thus far remained a mystery. It was the imru (ymrw) which, mixed with honey, he applied in cases of great soreness of the tissues. Imru is believed to have been a mineral.

While the general content of his materia medica would not commend itself to modern surgery it is of interest to know that in the case of an infected necrotic wound in the breast he prescribed the earliest known external application of salicin in the form of a decoction of willow (salix) leaves. Probably his ancestors were taught by experience centuries earlier the antiseptic effect of its use.

Another application he used for allaying inflammation contained dung, and was probably ammoniacal. His astringent application in this case, after he had reduced the inflammation, was a solution containing copper and sodium salts.

In two cases at least he made a more extensive use of his pharmacopoeia. In case forty-one, an infected wound in the breast, this old surgeon prescribed a cooling application consisting of a decoction of willow bark; an astringent application of a solution containing copper and sodium salts as well as poultices of unidentified herbs. In the case of a prominent abscess in the breast he prescribes "two cooling applications, the second containing mason's mortar; a solution for allaying inflammation made of sycamore leaves, acacia leaves and ox-dung; an astringent solution containing copper and sodium salts and a poultice of herbs."

The surgical student, for whom this book seems to have been compiled, was instructed carefully to watch for signs of paralysis:

"Instructions in regard to treatment of the perforation of the temporal bone: If thou findest that man to be silent, and he does not speak, thou shouldst soften his head with grease, pour (an unidentified medicament) into his ears: He may put his hands to his eyes but not realize that he is doing it."

A test for paralysis often repeated in the text is:

"Tell thy patient to look over his right and over his left shoulder and at his breast, if he is able to do so."

In fact, one is led to believe that this manuscript may have been a text-book in that first college of medicine in the history of the world—The Hall of the House of Life, which King Darius I of Persia had Uzahor-resenet restore.

In the sixth century B. C. under the patronage of Darius, whom Professor Breasted characterizes as "the greatest and most enlightened administrator of the early world before the rise of the Romans," was Uzahor-resenet, an Egyptian ecclesiastic, a high priest of the Goddess Neith at her temple in the

Delta city of Sais. This priestly aristocrat's statue, now in the Vatican at Rome, carried an inscription which says:

His Majesty King Darius commanded me to come to Egypt while His Majesty was in Elam as Great King of every country and Chief Prince of Egypt, in order to establish the Hall of the House of Life.

I did as His Majesty had commanded me. I equipped them with all their students from among sons of men of consequence, no sons of the poor were among them. I placed them under the hand of every wise man for all their work—I equipped them with all their needs, with all their instruments, which were in the writing, according to what was in them aforetime.

His Majesty did this because he knew the value of this art in order to save the life of every one having sickness.

Professor Breasted believes that the term "Hall of the House of Life" was an old one applied to archive chambers, libraries and the like, and probably refers to such a place rather than to a hospital. He adds:

In this remarkable inscription (on Uzahorresenet's statue) we find the earliest known mention of a medical school as a royal foundation. It is important to note that this Egyptian medical school at Sais was not being founded for the first time, but was being restored as the surviving old writings in Uzahorresenet's hands showed him it had been "aforetime."

We note with interest that the medical students of the sixth century B. C. in Egypt were selected from families of good social station, and that, as the last lines show, these young physicians were evidently also priests in the temple of the Goddess. Indeed the High Priest himself, Uzahor-resenet, bore the title "Chief Physician." Among the branches of instruction the reference to "instruments" shows us that surgery was included.

Among these highly civilized cities of the Nile Delta, the first large cities the Greeks had ever seen, the Macedonian kings of Egypt set up their enlightened scientific foundations at Alexandria. We see now that in medicine at least Darius had anticipated them. The important point to note is the fact that the support of old Egyptian medical instruction was continued by the Persians after their conquest of Egypt (525 B. C.). When, two centuries later, the Alexandrian physicians began to enjoy the princely support of the Ptolemies, they found themselves among the surviving native Egyptian medical schools and medical libraries of the Delta, when such contacts and influences as we have suggested could hardly have been escaped.

The ancient history of the Smith Papyrus as a whole, says Professor Breasted, illustrates the hazards which beset such records and their meager prospects of survival.

"It is now, without doubt," he adds, "thousands of years since the original copies of this surgical treatise, as penned by the hand of the nameless author himself, probably nearly 5,000 years ago, has disappeared or been destroyed. A copy survived the fall of the old kingdom 3000–2500 B. C. and its successive copies survived the fall of the middle kingdom, in the early eighteenth century B. C. and the advent of the Hyksos."

Professor Breasted believes that it was at this time, when upper Egypt was striving to throw off the foreign yoke of the Hyksos, a Theban scribe copied the ancient treatise on surgery which in content was then probably over a thousand years old.

Professor Breasted writes in his introduction to the translation:

It was as if a man to-day sat down to copy a manuscript written in the reign of Charlemagne, full of old words and archaic terms of speech.

The scribe was master of a stately and beautiful book hand, but he was totally ignorant of medicine, and when confronted with some highly specialized picture-sign, like that of the hewn mandible, he completely lost his ready command of his graceful and running form and awkwardly smeared together a blotted and angular picture.

He was excessively inaccurate, but occasionally noticed and corrected his errors—in one case placing an omitted word in the margin and calling attention to it by a cross, the earliest known asterisk in the history of book-making. He may have been an employe on the staff of some ancient copyist's office. In any case when he had copied the old treatise on surgery from

the beginning (the human head) down to the thorax and the spine he stopped in the middle of a case, in the middle of a line, in the middle of a sentence, and leaving the end of the long roll bare of all writing for some space, he turned it over and copied on the unwritten back a series of incantations against pestilence, to which he added three recipes, one for female troubles and two for improving the complexion. It is possible that the first purchaser, some local Theban practitioner who saw the unfinished treatise on surgery, ordered the scribe to stop and to copy for him this unsavory magical hodge-podge on the back.

Eventually this unknown owner probably handed on the roll to some later worthy in the same craft. The last owner was much attracted by a roll containing a recipe for "transforming an old man into a youth," and he, or some scribe for him, took pains to copy this at the end of the older material collected by his predecessors.

Meantime much handling and daily use of the document had frayed the beginning of the roll and at least one column of the fine old Book of Surgery containing the title of the book (with perhaps the name of the author) and the beginning of the first case dropped off in tatters.

When at last the village quack himself fell sick and found his art unable to exorcise the demons of disease, his surviving relatives doubtless carried him up and laid him away in a rock tomb in the great Theban cemetery. Luckily for us, they seem to have laid his roll in his coffin with him; for it is hardly likely to have survived in any other conceivable place. There in his tomb it reposed in perfect safety throughout a vast sweep of human history for some three and a half millenniums, from the migrations of the Hebrew patriarchs and the prehistoric wanderings of the Greek barbarians to the American Civil War.

The modern descendants of the old Egyptian quack, searching the tombs for salable plunder, probably found the roll beside the body of their Theban ancestor and saw in it prospects of gain. Unfortunately, however, our information on this point is not conclusive.

The modern vandals stripped off the tatters of papyrus still hanging on the outside, to make it look more "ship-shape." After selling this roll to Mr. Edwin Smith in January, 1862, they patched up another out of indiscriminate rubbish and gave it the appearance of a papyrus roll by wrapping it and gluing in place the tattered fragments which they had stripped off the genuine roll. Two months after the first sale they put this dummy roll also on the market and sold it, likewise to Mr. Smith. Detecting the fraud, Mr. Smith recognized and rescued the new fragments of the precious medical book, thus recovering for science an extraordinary, even though fragmentary, discussion of the heart and its system of canals.

BOTANICAL EXPLORATIONS IN THE ROCKY MOUNTAINS—THE LOLO TRAIL

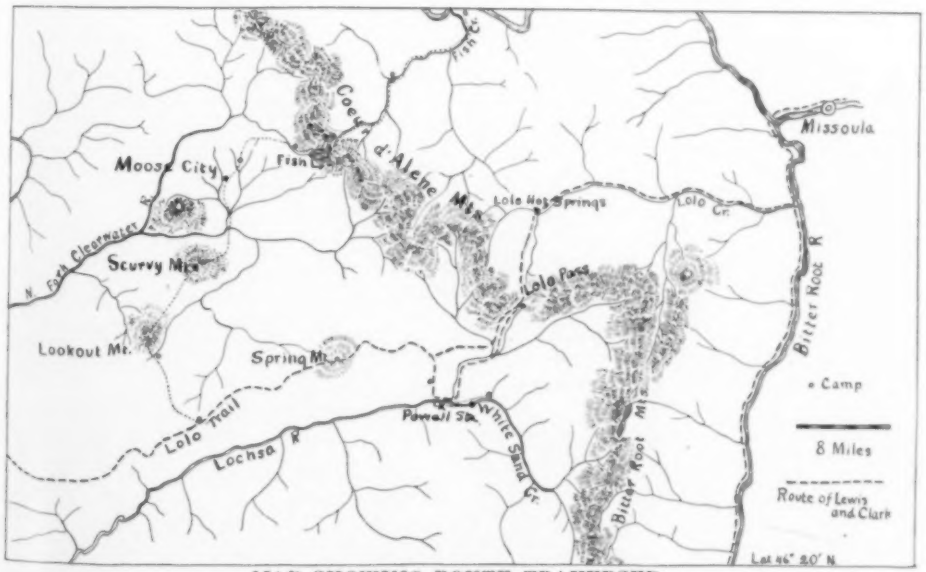
By Professor J. E. KIRKWOOD
THE UNIVERSITY OF MONTANA

LEAVING Missoula one bright afternoon in August, 1924, we took the river road down the Clark's Fork. The broad intermountain valley lay about us, the fields in mid-harvest. A few miles away the land rose in smoothly rounded foothills, which gradually merged into the timbered mountain sides above, dark green with Douglas spruce and yellow pine. In all directions clearly visible in the grassland, the level shorelines of an ancient lake lay one above another in narrow terraces to a thousand feet above the valley floor.

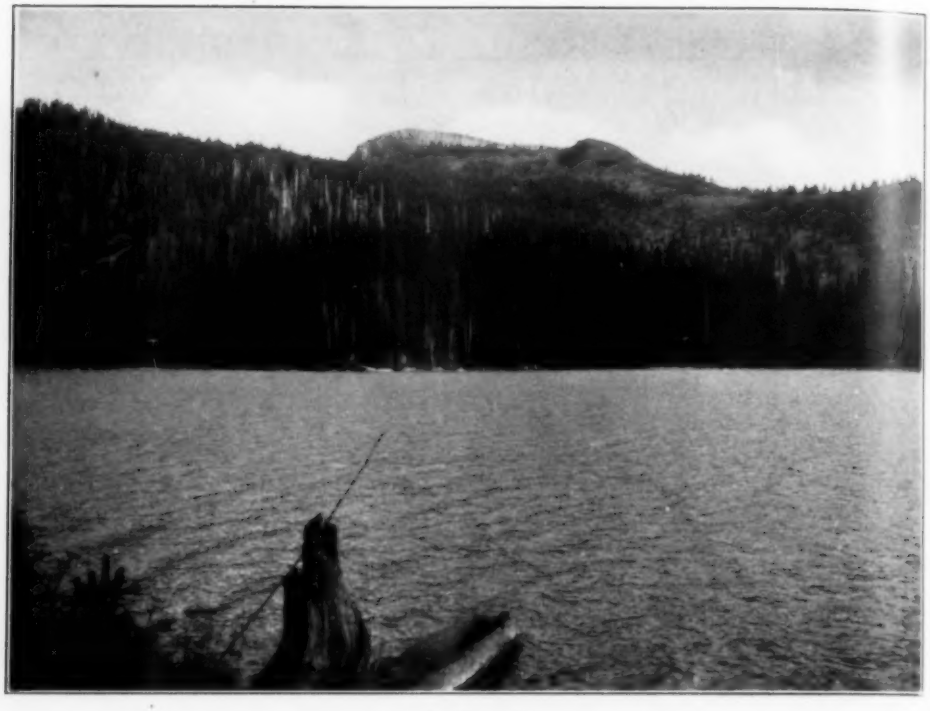
Below Missoula about twenty miles the valley narrows to a canyon and continues so for the most part during the rest of its course, or until it reaches Lake Pend d'Oreille, two hundred miles to the northwest. The road now becomes an interesting and picturesque drive with a new vista at every turn, as it rises over hills or skirts the stream along narrow ledges.

Forty miles from Missoula a narrow road leaves the highway and after winding about for some time among the pines arrives at Cyr's ranch, which marks one of the starting points for the Clearwater wilderness. Here we left the auto for the pack train and saddle.

Our party consisted of Mr. Vital Cyr, Mr. Richard (Dick) Johnson, Robert Kirkwood and his father, the writer. Mr. Cyr, whom we had engaged as guide and packer, is a member of an old family



MAP SHOWING ROUTE TRAVERSED
ACROSS THE COEUR D'ALENE AND BITTER ROOT MOUNTAINS AND THROUGH PARTS OF THE CLARK'S FORK AND CLEARWATER DRAINAGE.



FISH LAKE,
NEAR THE SUMMIT OF THE COEUR D'ALENE MOUNTAINS.

of French pioneers and well known throughout western Montana for his efficient service to hunters and others entering the extensive wilderness which begins, so to speak, at his back door. Dick, our cook and assistant packer, is a Swede of some forty years, a good fellow, an expert woodsman and a master of camp cuisine. Robert, drawn primarily by the lure of forest and stream, aided materially in the preparation of the collections to which the writer must needs give first attention, although himself far from insensible to the joys of an outing in the deep wilds of the Clearwater. Notwithstanding the unfortunate ending of our trip of the previous year, across the Bitter Roots farther south, we addressed ourselves to this adventure with high spirits.

Cyr's ranch lies at the mouth of Fish Creek, which enters the Clark's Fork from the south. The creek is about thirty miles long from its main source to its mouth, but is fed by many tributaries flowing down from the wooded slopes of twenty-five miles or more of the Coeur d'Alene Mountains. All the way along the swift and stony course its limpid waters are famed for trout, which makes it a delightful place of summer recreation. Along this beautiful stream our trail wound in and out among the pines or followed the ledges above its clear pools. About eight miles above its mouth the stream divides into the North and South forks. Our trail bears to the right and follows the North fork to Clearwater Crossing. Here another trail comes in from Quartz on the railroad northward.

From the mouth of Fish Creek to Clearwater Crossing the vegetation passed through the usual transitions

from the open river valley into the narrow mountain canyons without great increase in elevation. On this day we had hardly ascended five hundred feet, but passed from the arid transition zone of the yellow pine (*P. ponderosa*) into the Canadian or montane zone with its lodgepole (*P. contorta*) forest and accompanying species. The Douglas spruce is freely intermixed along the way. These are the main arborescent species of the uplands. Along the streams the black cottonwood (*Populus trichocarpa*) is conspicuous and overtops the birch (*Betula fontinalis*), alder (*Alnus tenuifolia*) and thick shrubby growth of cornel (*Cornus stolonifera*) and various willows with occasional Cascara (*Rhamnus Purshiana*). In the upper burned region, especially about the Crossing, the southern slopes are strikingly characterized by scattered clumps of mountain balm (*Ceanothus velutinus*).

The Fish Creek trail is one of the historic highways of western Montana. It was built in 1869–70 and served as a means of reaching the then important placer gold camp of Moose City. Though now improved, it still follows in many places the original location and is worn knee deep here and there by years of travel and erosion. Over it passed in that day most of the traffic from the western Montana settlements, long pack-trains of supplies and mining equipment, machinery carried piecemeal on the backs of mules and horses, herds of beef cattle, men on foot and horseback.

The Crossing marked the end of our first day. Here a log cabin stood hospitably open and near it a corral. Packs off, the horses turned eagerly to grazing and we to our camp and the evening meal. Other parties soon pulled in at this mountain crossroads, which is a favorite spot because of its shelter and feed. Exchange of news and comment was cordial and ready as we cooked and ate together and passed the evening hours.

Rain came in the night and morning opened with a drizzle. From the Crossing the trail rises steadily and often

CAMP ON FISH LAKE CREEK

FOREST OF SUBALPINE FIR (*Abies lasiocarpa*), ENGELMANN SPRUCE (*Picea Engelmanni*) AND MOUNTAIN HEMLOCK (*Tsuga Mertensiana*). IN THE FOREGROUND CONE-FLOWER (*Rudbeckia occidentalis*). NOTE THE POLE TO MARK THE CABIN IN THE DEEP SNOWS.

ALL THAT'S LEFT OF MOOSE CITY

A FLOURISHING GOLD CAMP OF THE SEVENTIES. NOW GROWN UP TO A FOREST OF WESTERN WHITE PINE (*Pinus monticola*).

sharply. It soon enters a thickly wooded glen, where the dank forest supports a thick and tangled undergrowth rising among fallen and rotting logs. Arbor vitae is abundant, indicating the most humid forest conditions that we had yet seen. The northern slope, sheltered from wind and sun with lingering snow and slow evaporation, feeds countless springs and small streams and nourishes a dense vegetation, which in turn reacts on the conservation of moisture in striking contrast to the opposing slopes facing the south.

We ascended over slippery slope and boggy flat, the rain falling almost constantly, and boughs and bushes sagging with their weight of water drenched us anew at every touch. The West Fork was now a roaring series of cascades leaping from ledge to ledge, white with foam. From the cabin we rose three thousand feet and in ten miles crossed the summit and the Montana-Idaho line at 6,400 feet.

The top of the ridge has a broad and gently rolling contour. Its most interesting feature is a park-like forest of mountain hemlock (*Tsuga Mertensiana*). The thick and dark green foliage, the drooping branchlets and cone-like form of the crown drew our attention at once. Its presence here was expected, although it has a very limited range in the Rocky Mountains and this was near the southern border of its area; from here it extends northward to Alaska and thence south along the Cascade mountains to the high sierras of California. Its occurrence is mostly sub-alpine among spruces and firs, often in bleak and wind-swept situations. It is plentiful throughout the Coeur d'Alene Mountains at altitudes from 5,000 feet upwards, where, however, few peaks rise to as much as 8,000 feet.

In the canyon of a small stream, we pitched camp a few miles below Fish Lake in an open glade or meadow, flanked on the north by a dense forest and open toward the southwest, where rose a high and barren ridge. The heavy precipitation is reflected in the character of the vegetation, which is everywhere dense and luxuriant. This type of meadow is of the "weedy" sort, thickly upgrown with rank herbs, chiefly cone

flower (*Rudbeckia occidentalis*) with tall larkspur (*Delphinium glaucum*), monkshood (*Aconitum columbianum*), cow parsnip (*Heracleum lanatum*) and species of *Saussurea* and *Senecio*. In other meadows grass associations are dominant, apparently lacking the conditions of precipitation and humidity necessary for the formation of the weedy type. The forest also is of the moisture-loving species, hemlock, spruce and fir, and where not too dense, with almost impenetrable stands of snow brush (*Menziesia ferruginea*), especially on northern exposures.

The precipitation here is largely in the form of snow, which is said to accumulate during the long winters to depths of ten or fifteen feet. Indications of this fact appear in a novel sort of way. On this flat stood a crude, heavily constructed log cabin, from the roof of which rose a pole like a flagstaff as a marker for the location of the house. Most of the cabins of this sort are built by trappers whose lonely and arduous work takes them over many leagues of the wilderness through the dead of winter. A line of traps may be laid out in a loop of one hundred and fifty miles, with cabins at convenient intervals as refuges at night or in stormy weather. Under this deep blanket of snow the local aspects of the country are obliterated; little creeks, trails, bushes and small trees are entirely covered and the trapper's course is laid by the main topographic landmarks. Coming to the approximate location of the cabin its exact spot may be detected by the pole sticking up through the snow.

Two days were spent at this place waiting for the rain to abate. In spite of the rain some collections were made, but plants collected under such conditions are dried with difficulty. But as time was going by at the rate of $18.00 per day, we could ill afford to be idle and made shift as well as possible. A log fire before the door of the tent spread its welcome warmth through the interior, where driers strung on cords were rendered serviceable and applied with sufficient frequency to dry the specimens

MOOSE CREEK BUTTES AND THE BURNED FOREST.

GEM LAKE UNDER SUMMIT OF SCURVY MOUNTAIN. SUB-ALPINE FIRS

without much delay. On the third night, however, the sky cleared and preparations were made to break camp in the morning.

From this little meadow which we called Cyr's Camp, we proceeded down the little Fish Lake Creek, crossed it and ascended a flank of Osier Ridge. The trail leads now nearly west for about six miles, passing over the summit at an altitude of approximately 6,860 feet. Here the mountain hemlock, Engelmann spruce, sub-alpine fir and white bark pine were growing intermingled in a clean open forest and with scant undergrowth as we swung onto the southern slope. Even in this region, where the precipitation is relatively heavy, though mostly from October to May, the potent desiccating influences of sun and wind leave their imprint on the vegetation in half the circle of a hill.

Turning abruptly south from the west shoulder of Osier, we were soon deep in a forest of white pine (*P. monticola*) and arbor vitae, which grew higher and more dense as we descended to lower levels. So deep was the shade that the sunlight hardly filtered through the dense canopy of branches and the ground was often bare of any vegetation, save an occasional toadstool, which rose out of

the mat of decaying leaves. About us on every hand the thick gray columns ascended to somewhere in the labyrinth of foliage between us and the sky. In the jungle to our right the trickle of a little stream was heard and the remains of crude shelters of leaning poles appeared among the trees. Dick informed us that we were at "Shina" Spring and recounted to us some of the early history of the Chinese in the mining locality which we were now entering.

A night spent at the Alma Mine on Osier Creek, a few collections made along the stream and we resumed our journey. In an hour or less we came to the site of old Moose City. One tumbledown log cabin now remains of all that once was a roaring gold camp of over 3,000 people. A vigorous young forest of white pine of thirty to forty feet now stands thickly over the streets and lots of the old town, and nothing breaks the silence save the native cries of the wilderness, which has reclaimed its own. Here in the early seventies the life of the camp was at its height. The gold of the gravels, rich in places, finally played out and the scene relapsed into the silence from which it came. Brought about by natural forces the concentration of the gold in these narrow gulches has led to hopeful exploration of the surrounding hills in search of the mother lode but without success. Probably the hope is not well-founded, since the drift of the free gold to the stream gravels would tend to magnify the prospect.

From Moose City our way lay down Independence and Moose Creeks to Kelley Creek, which we crossed just above its junction with Moose. We passed a fire camp and a new burn which had cleaned up a few hundred acres of dead timber, killed by the fire of 1910. Viewing the rest of the desolate waste of dry and bleaching skeletons we could not feel much regret at the riddance of rubbish that littered the ground. It was fourteen years since the first fire had swept through, and the trunks of a fine forest of white pine and cedar stand thickly over hundreds of square miles of the Clearwater country. From high points, often as far as the eye can reach, this scene of desolation spreads with unvarying and depressing monotony.

In this burn the dead trees are now rotted in the ground and slight winds bring them down in numbers. Eventually they will form an intricate and impassable tangle of debris, dry and splintered, a mass of material ready for a fire more intense than the first. And fires are inevitable. A single electric storm may start several of them. Given what may easily happen—a dry season, electric discharges accompanied by little rain, a high wind, fires started in inaccessible places and no fire-fighting crews or equipment would be able to cope with the situation.

The burn has come up to a growth of willows and other shrubs, native herbaceous plants and a coniferous growth of little consequence in many places because of its sparseness and the inferior species it represents. But whatever the growth under these conditions it seems to be foredoomed. It hasn't one chance in a hundred of coming to maturity before being caught by a devastating fire. Every year is an added risk, augmented by the time represented in the young growth. With such reflections in mind one can hardly escape the conclusion that the earlier the slate is wiped clean the better. The menace in such a fire is that it is likely to spread to new areas of green timber, and this menace, it must be admitted, is considerable. A cleanswept area of course must be planted if too large to be seeded from the side which, over such an area as the Clearwater, is impossible. Planting, truly, is costly. The only question is which is likely to be more costly, trusting to chance in the face of serious hazards, or allowing fires to clean up the deadened areas. Fire-fighting also is costly and the question

THE DEVIL'S CHAIR
SCENE ALONG THE LOLO TRAIL.

may be asked as to whether the present growth with the ultimate risks involved is worth the outlay it takes to protect it.

The dominant shrubs throughout the burn are Scouler's willow and thimble berry. Along the stream hawthorn, cornel, alder and willow grow in dense thickets. A few scattering saplings of lodgepole pine and here and there a young white pine could be found. Hardly a single mature green tree appears within our range of vision except toward some of the distant and higher elevations.

From Kelley Creek we ascended a well-built trail along the northwest slope of Scurvy Mountain. Passing through the burn we came later upon scattering hemlocks and firs mingled with white bark pine and patches of alder, spiraea, mountain balm; and bear grass constituting most of the undergrowth. Near the summit of the trail a cabin sheltered two young men who kept the lookout station on the peak a quarter of a mile or so to the north. We were heartily welcomed and offered such accommodations as the place afforded. An excellent spring, some shade and plenty of feed decided the matter and we prepared to sojourn here the balance of this day and the next.

Under the peak of Scurvy Mountain, on the east side about six hundred feet down, nestles a beautiful little lake. As the map assigns no name the writer suggested Gem Lake as an appropriate designation. It is fed by springs and melting snows and empties by a little stream which descends by a steep and narrow gulch to Kelley Creek. Around this lake grow grasses, sedges, peat moss entangled with violets, heaths (*Ledum*, *Kalmia* and *Menziesia*) and willows, and back of all a fringe of tall and spire-like firs. The cold waters of the little lake are deep and clear, and near the shore float the long slender streamers of a delicate bur-reed (*Sparganium angustifolium*).

From Scurvy Mountain our way led south over the top of Lookout Mountain at 6,900 feet and thence easterly to the

Lolo Trail at Indian Graves. Most of the ground traversed was through old fire-killed timber, under which a vigorous growth of thimbleberry and willows occupied most of the ground, save where acres of *Gnaphalium sulphurescens* gave a whitish cast to the landscape. Little of interest marked these miles except around our evening camp at the head of Monroe Creek, where a beautiful meadow, bedecked with the colors of groundsel, monkey flower, harebell and gentian, was divided by a clear, little stream fringed by low sedges. Like an oasis in the desert, this field of green and blue and gold gave us refreshing rest in the midst of a wide wilderness of death.

The Lolo Trail, which we touched for the first time at Indian Graves, is an ancient Indian highway which follows the divide between the North Fork of the Clearwater and the Lochsa. It was an old trail, no one knows how old, when Lewis and Clark were the first white men to travel it in 1805. It was the main route from the lower Snake River region and the Nez Perce country to the plains of the Missouri via the Clarks Fork and Blackfoot Rivers. Over this trail Chief Joseph and his people made their memorable march. The feet of countless ponies have cut deep into the soil, have abandoned these ruts and made others alongside. Hoofs and travois have worn a wide road, keeping in true Indian fashion to the highest ground, which was often steep and difficult but comparatively free of brush and fallen timber.

From Indian Graves we followed the trail up the ridge to the northeast. Most of this ridge still bears its virgin trees and many a mile of the trail lies through beautiful forest aisles. The mountain hemlock and white pine in more favored places form high forests with cool and deep shade. On the drier ridges they give place to lodgepole pine in mature open stands, with few companions save the widespread and dominant bear grass. In younger stands of lodgepole the low red huckleberry (*Vaccinium scoparium*) is usually the prevailing ground cover, the bear grass coming in later. The two, however, often appear together under the lodgepole canopy. Sub-alpine fir and spruce also abound, especially in gulches and wet soils.

Impressive rock formations appear. The granite weathers in massive columns and huge boulders, standing out upon the mountain side or rising isolated in the midst of the forest. One group of unusual form is known as the Devil's Chair. They were not observed on the Selway or the Clearwater and seem for some reason to occur along this divide and in near localities.

This was a long day's trip. Twenty miles with a pack outfit over a rough trail is about enough for one day. Feed without water, or water and no feed was an impossible camp, so we pushed on, the longest twenty miles it seemed that we had seen in many a day. The sun was sinking low, so we made camp on top of Spring Mountain. A spring by the trailside about a quarter of a mile below the top of the hill must be the feature alluded to in the name, for no other water was found. Some forage was scattered among the tufts of bear grass, but evidently not much, for the horses dispersed widely in search of it. The wind blew cold, and without shelter of hill or forest we made the best of an uncomfortable camp. Lewis and Clark stopped here on their return journey in 1806. This being in June, the young herbage seems to have been sufficient for their stock, but in the fall of the year we were not so fortunate.

No regrets were felt at leaving Spring Mountain. We were early on the trail, which nearly all day led through green forests. The beautiful scenes along this ridge still linger in the memory, although many of them are preserved in more durable form.

At one point that day we met a solitary traveler with a lone pack-horse on

THE LOLO TRAIL

FOREST OF MOUNTAIN HEMLOCK. UNDERGROWTH OF SNOWBRUSH (*Menziesia ferruginea*) AND BEAR GRASS (*Xerophyllum Douglasii*).

his way to Lewiston, Idaho, apparently an itinerant prospector, whom our packers facetiously referred to as a "coffee cooler." Having exchanged the usual salutations we improved the opportunity to inquire as to the trail that lay ahead of us and to locate, if possible, some of its doubtful points. He volunteered the information that he had been misdirected via the river trail and had to climb up out of the canyon onto the ridge. "I just came up that ——— hill," he added, with further maledictions upon his misinformers.

Evidently the trail which he so feelingly described was the Powell branch of the Lolo Trail, which led to Lolo Pass by way of the river in the interests of salmon fishing, as recorded by Lewis and Clark. The other branch kept straight on along the highlands. This fork of the trail we had been looking for for some time and were somewhat uncertain lest we had passed it, as some of the cutoffs were unmarked and indistinct. We were now set at rest by the stranger as to the location of this point and arrived at Powell Junction about two P. M., where we were to await the arrival of the pack train.

As luck would have it, we found the ridge trail beyond the junction blockaded by fallen timber and so were compelled to take the route via the Lochsa, down the trail that our chance acquaintance had recently ascended, and soon found for ourselves that it was quite worthy of his ardent comments. Straight

down Parachute Hill it goes, a quarter mile perhaps at the steepest, and the horses had little to do but slide.

At the bottom of the hill ran a clear little stream flanked with alders, and in an open glade of the forest we pitched camp. On a big spruce under whose sheltering arms we threw our packs were carved the words "Bear Camp." Nearby was a muddy swale, in which were several slimy bear wallows, whence, probably, the name. Tall firs, spruces and lodgepole pine surrounded us and we were in quite the opposite condition to that of the previous night on Spring Mountain. A high wind roared in the trees on the ridges above, but not a breath of air stirred about the camp. Nevertheless a thick layer of ice formed in the water pail that night, the 29th of August.

From Bear Camp the trail drops one thousand feet to the Lochsa River. The grade is easy and the way lies through deep forests of grand fir and arbor vitae. Here and there beautiful open glades abound in fresh and luxuriant vegetation despite the cold nights. In the deep shade of the forest, however, little grows save a few pale ferns, which is in marked contrast to the plant life of the day before at 2,000 feet higher, where lodgepole and bear grass prevailed in the open forest, or in the burn where mountain balm and spiraea bordered the trail, mingled with asters and fleabane.

An hour or two brought us to Powell Ranger Station, where a well-built log house and corrals stood on a flat near the river. Here the trails are wide and improved, of easy grade, crossing the stream by bridges instead of fords, and providing facility in the movement of supplies, so essential in the case of fire.

A short distance above Powell Station the Crooked Fork and White Sand Creek unite to form the Lochsa River. They are both beautiful streams and with their numerous feeders drain over seventy miles of the western slope of the high Bitter Roots and Coeur d'Alenes. At this time of year both streams are easily fordable at most places, but the broad stream beds, bare rocks and gravel bars show that a huge volume of water pours down these channels from time to time. Their clear cold waters flow from numberless alpine meadows and little hidden lakes.

A road is now building down the Lochsa from Montana into Idaho. Sad fact! The days of the virgin wilderness

KELLY CREEK BASIN FROM SCURVY MOUNTAIN

AT THE END OF THE TRIP

AT LOLO HOT SPRINGS. FROM THE LEFT, RICHARD JOHNSON, THE WRITER, AND VITAL CYR.

are numbered. Nothing in park or garden or human haunts has quite the charm of nature's untarnished beauty in these remote wilds, where flowers bloom untrampled and the forest primeval has never felt the ravages of the axe and saw. The road brings the auto, and the auto brings the tourist and the camper. Every lovely streamside will be littered with papers and tin cans. In autos come loads of fishermen who ply their rods up and down every stream until the trout vanish. Come the hunters and the despoilers until nothing is left but the landscape. All these things must be, of course, but the nature lover views the passing of the primitive solitudes with a pang of regret.

Cabin Creek is a little stream that tumbles noisily over many boulders on its way to White Sand. Here we threw off the packs and let the horses go. The bright sun of noon shone down through the pines and scattered checkered shadows over the ground. It was a beautiful day. The flashing riffles of the White Sand invited our flies and the willow copses and verdant banks promised interesting additions to the plant press.

The trail from Powell Station to Lolo Springs follows the left bank of the Crooked Fork. At Brushy Fork it enters Pack Creek Canyon and rises steadily to its junction with the old Lolo Trail near Packers Meadows. Again the

day was spent in the deep forests, which filled the gulches with cedar and fir. Occasional burns were passed, but the trail was fair and we made good time. Gradually the roar of Pack Creek became less vociferous, the way less steep, the bottoms broadened into reedy flats and low willow thickets. We were nearing the Meadows. Here the forest grew silent, and as the sun sank toward the wooded ridge to the west we emerged upon the edge of an extensive grassy area which marks the approach to Lolo Pass from the west. Here we pitched camp where Pack Creek had dwindled to a mere rivulet and spent the evening hours exploring the botanical possibilities of the flats, adding to our collections gentians, asters and other plants which we had not met before.

Packers Meadows is a beautiful area of grassland surrounded by pine forests. A meandering stream makes its sluggish way westward and the trail cuts across in a northerly direction to drop down on the Clarks Fork drainage. So slight is the rise that it is hardly perceptible, and only when the water is seen flowing the other way does one realize that the divide has been passed. The altitude of the pass is only 5,254 feet. Lewis calls attention to the abundance of the Camas in these meadows and to the evidence here of frequent encampments of Indians in their journeys along this trail.

The night was clear and cold and a heavy frost descended upon our beds. The tinkle of the horse bells came down the meadow, and as the fire flickered out we resigned ourselves to dreams of marching figures in buckskins and furs, who through the past have made history along this storied highway.

All too soon, however, the sound of a crackling fire and of Dick operating among the camp utensils roused us to consciousness of another day. From blankets to creek on a cold morning is an abrupt transition but invigorating. How cold water washes the sleep out of the eyes! The blood tingles and the zest for breakfast brooks no delay. Flapjacks, butter and syrup, bacon, trout and coffee—what more is needed for the beginning of a perfect day! Came once more the rolling of blankets and the stowing of packs, the rounding up of reluctant horses and the cinching of saddles. Once more we strung out along the old trail, across the wide meadow and through the Pass.

Lolo Hot Springs are described in the journal of Lewis and Clark, who passed here on their westward trip September 13, 1805, and on their return camped at this spot on June 29 of the following year. The Indians were then impounding the waters of the hot springs and using them as baths, and now a hotel and bath houses and a considerable cluster of cabins and tents mark the site of a rapidly growing summer resort within easy drive of Missoula.

The Lolo is one of the larger creeks flowing east out of the Bitter Root Mountains. One fork of it rises near Packer's Meadows, which, added to many others, makes a beautiful little stream which goes gliding over its gravels toward the Bitter Root River. Its fall is moderate, so it is not a foaming torrent like those that pour down the steeper gulches. Before the building of the road, wagons followed the stream bed much of the way, the waters being shallow, and even now we cross it frequently on low wooden bridges. As it curves from side to side we catch vistas down its course with its clear waters dancing and sparkling in the sun, its banks fringed here with alders, there with broad gravel bars or a green flat. Shallow pools are filled with cresses or the feathered stems of the white water crowfoot (*Batrachium*), bordered by yellow monkey flower (*Mimulus langsdorfii*). Bunches of senecio (*S. triangularis*) with yellow flowers rise here and

there, and occasionally a tall monk's hood (*A. columbianum*) lifts a panicle of purple flowers.

The canyon of the Lolo lies between bluffs that rise abruptly and then fall away in more gentle slopes to the more distant and higher elevations. Their slopes are timbered except for minor areas long since swept by fires and now occupied by shrubby growth. As the course of the canyon lies east and west one slope is shaded while the other receives the perpendicular rays of the summer's sun. The comparatively light rainfall leads to a strong differentiation of the vegetation in relation to exposure. North facing slopes are thickly forested along the whole length of this canyon, the opposite slope sparsely wooded, mostly with yellow pine and Douglas spruce, increasing in density with higher and more humid levels. In the upper canyon both slopes are more nearly alike, but toward the mouth of the valley even the drouth-resistant pine gradually yields to bunch grass and sage (*Artemisia tridentata*) or rabbit brush (*Chrysothamnus nauseosus*).

Ten miles from its mouth the canyon opens out into a valley, at places half a mile in width, occupied by attractive little farms with an air of prosperity. Their fields, now sere in the approaching autumn, were lately occupied by waving grains and rich meadow grasses. Orchards laden with ripening apples and fat stock grazing in the fields fill the picture of rural life. Only one blight rests upon this pretty scene, the specter of the spotted fever. Now and then, not often, but here and there comes the fatal touch of this mysterious malady.

Mount Lolo, a few miles to the south, rises to 9,000 feet, bold and massive. Its forests are bluish in the early autumn haze. Above its broad shoulders rises a rounded rocky summit, in the lee of which lie a few drifts of last winter's snow. In a few weeks the larch leaves will be turning yellow and then the lower slopes will display the location of *Larix occidentalis*, while around the summit like a wreath at the timber line will appear in equally brilliant color the zone of *Larix Lyallii*. Between these two will extend the broad and uninterrupted belt of dark-hued pine and spruce.

We are still upon the historic route of Lewis and Clark. In their westward trip of 1905 and their return in 1906, they traversed the whole length of Lolo Canyon. At the mouth of the canyon now stands a bronze tablet to the memory of these intrepid explorers. The main features of the landscape and the flora probably remain much as they saw them, save for the towns, farms and roadways which even yet have not penetrated deeply into the wilderness nor ventured far from the main streams and ancient highways.

GRASSHOPPERS AND THEIR ALLIES[1]

By Dr. ANDREW N. CAUDELL

Of all the insects which annoy mankind none do more real and serious damage than grasshoppers. From time immemorial these insects have devoured the vegetation of the earth, and the biblical narratives of havoc wrought in early days describe invasions no more serious than others of almost annual occurrence in some part or other of the world at the present time.

The damage done by grasshoppers consists chiefly in the destruction of grasses and of grains which are devoured by them; but some years ago there came to my attention an authentic case of a ranchman in Montana having lost four cows from their having eaten large quantities of grasshoppers which they were unable to digest. Chickens also were killed by eating too many of the insects, though in moderate quantities grasshoppers form a very good food for poultry.

The number of individual grasshoppers in a swarm is so very great as to seem utterly incredible. In 1898 a swarm passed over a ship off the Great Hanish Islands in the Red Sea which was estimated to contain no less than twenty-four thousand two hundred and forty billions of individuals weighing, at sixteen to an ounce, about forty-two thousand five hundred and eighty millions of tons. It is recorded that people have been made seasick by looking at masses of young grasshoppers which caused the surface of the ground to resemble the rolling billows of the sea.

In the early days of our own history our western states were occasionally overrun by hordes of grasshoppers which in a single night would entirely destroy extensive fields of grain, and in their migratory flight such swarms were so dense as to obscure the light of the sun for hours at a time. In passing over high mountains these flights encountered low temperatures, and as a result millions of the insects fell benumbed onto snow fields where they became embedded in the snow and eventually became incorporated in glacial ice. The Grasshopper Glacier in Montana is so named from the myriads of these insects scattered through its ice like raisins in a cake.

Fortunately conditions now have changed so that such immense invasions of grasshoppers no longer occur within our borders, though vast damage still is almost annually done through the ravages of a number of our native species.

So far it has not been possible wholly to subjugate our grasshopper enemies, but by the constant warfare waged against them the damage has been very materially lessened.

To some extent man counterbalances the damage done to his crops by grasshoppers by making use of them as food. Indeed, in some parts of Africa and Asia at the present time they are a very important article on the bill of fare of many native peoples. Thus in India many of the delicious curries are composed in greater part of grasshoppers ground up. In Arabia and other regions ground grasshoppers are used as a substitute for flour. In parts of Africa even the eggs are used, boiled up into a sort of soup.

It is prejudice alone that causes most people to look with disfavor upon insects

[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark, and given from Station WRC, Washington.

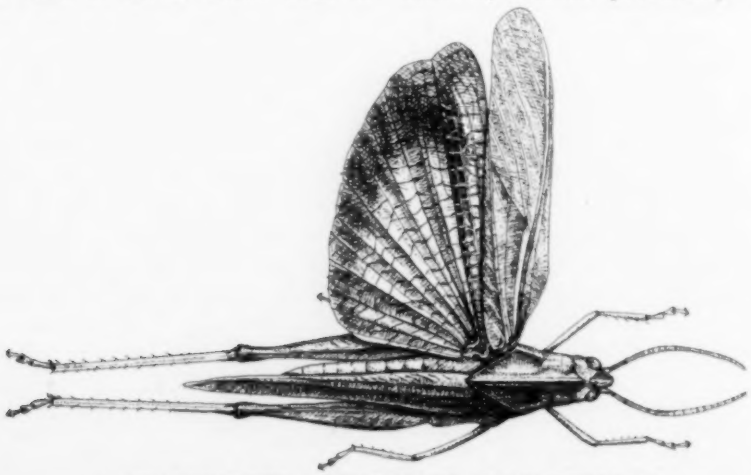
A GRASSHOPPER (*MELANOPLUS FEMURRUBRUM*)
ONE OF OUR COMMON INJURIOUS GRASSHOPPERS.

as food. Some of the leading entomologists of the country, speaking from personal experience, assure us that well-prepared grasshoppers form a very palatable dish. Why should well-cooked grasshoppers be less agreeable to us than raw and living oysters?

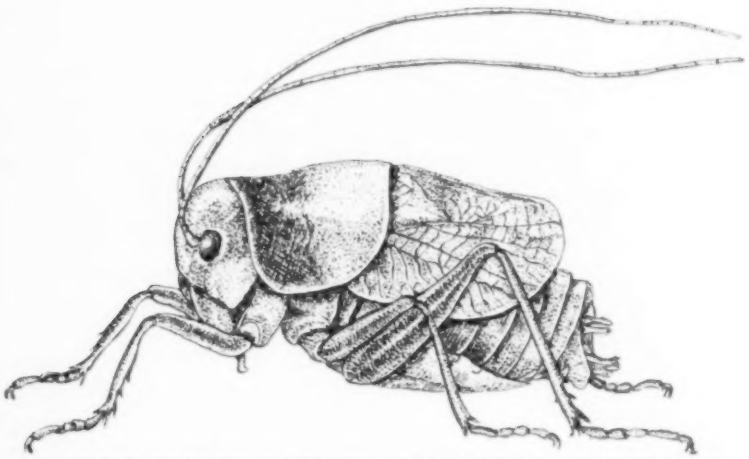
Although the most important use made of grasshoppers is to serve as food for man, they have been utilized in other ways. Great masses of them, at least as many as eighteen tons in a single year, have been shipped from South Africa to Holland, where the oil extracted from them was used for a special sort of airplane, it being particularly well suited for this purpose as it retains its liquid form at very high altitudes, and the residue was used as cattle feed. Tons of grasshoppers are also annually used as chicken feed.

Most grasshoppers are somber in color and are not especially attractive insects. But some vie with the brilliant butterflies in their gorgeous coloration, while others are provided with ornamental, sometimes bizarre, crests or other protuberances which impart to them an interesting or grotesque appearance.

Closely related to the grasshoppers are the katydids (Tettigonidae), insects scarcely less well known than the grasshoppers themselves. There are many different kinds of these. Most of them are green in color. Among them are some of the most renowned of the insect musicians, and these, together with the crickets, include practically all of the



A GRASSHOPPER (*TOMONOTUS FERRUGINOSUS*)
OCCURRING IN THE SOUTHWESTERN UNITED STATES, WITH THE LEFT WING SPREAD.



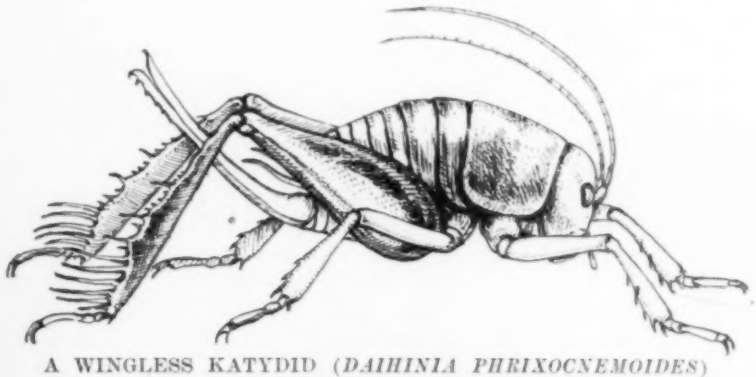
A SHORT-WINGED KATYDID (*CYPHODERRIS MONSTROSA*)
OCCURRING IN THE NORTHWESTERN UNITED STATES AND CANADA.

music makers which render our autumn evenings and nights so harmonious.

The music of the katydids is produced by special sound organs on the wings of the males, the females being without such special instruments and therefore incapable of producing loud notes. The fact that only the male is musical is not generally known. For instance, one poet commences one of his effusions "Thou art a female katydid, I know it by thy thrill," which may be good poetry, but is certainly deplorable entomology.

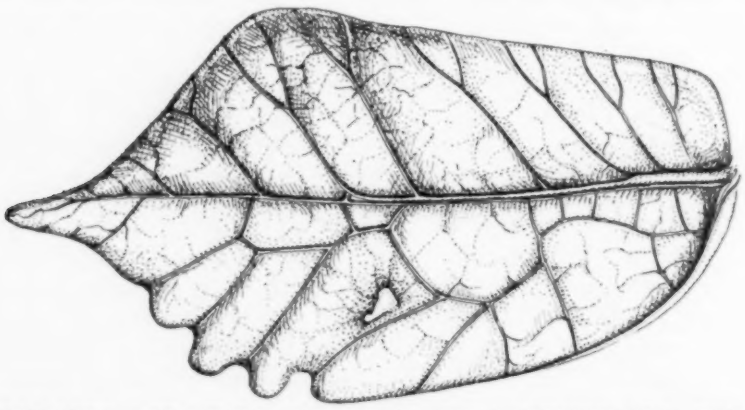
The true katydid, the one made famous by poets and classic writers, is by no means the one most generally known. In areas overgrown with tall trees this renowned musician passes its life entirely among the upper branches and seldom, if ever, descends voluntarily to the ground. With its broad, but rather short, wings it is incapable of sustained flight, its wings acting more as the planes of an airship and permitting a safe landing in case of necessity. Other longer winged katydids are more familiar to most of us, and are the ones most often seen and heard.

Most katydids lay their eggs in the pith of plants, under sheaths of grasses,



A WINGLESS KATYDID (*DAIHINIA PHRIXOCNEMOIDES*)
OCCURRING IN NEW MEXICO AND TEXAS.

between the two surfaces of leaves, or in similar situations, but a few lay them on the surface of leaves, or even in the ground. Unlike the female grasshoppers, which have no elongated egg-laying organ, the lady katydid possesses a sword-like appendage at the end of the body by means of which she inserts her eggs, one at a time, into the pith of plants or other places. This sword-like organ is in most kinds of katydids long and slender, sometimes longer even than the body itself, but in some it is short and stout. One of the most astonishing examples of what one of these insects is capable of doing in the way of splitting



THE LEAF-LIKE FORE WING OF A KATYDID (*TYPOPHYLLUM UNDATUM*)

substances into which it desires to place its eggs came recently to my attention. We all know on what compact and very thin paper railroad timetables are printed. One would scarcely believe it possible to split a piece of such paper, but a large green katydid from California actually performed this feat and inserted four or five eggs in the slit. It is necessary to see this piece of work to believe it possible.

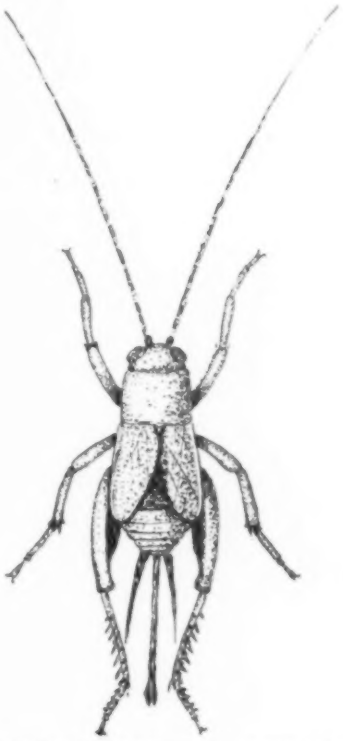
Katydids are not so renowned for their intelligence as are the ants and wasps, but the following illustration shows how one of them succeeds in outwitting the wily ant. In the tropics vast hordes of ants, the so-called army ant, march in almost solid masses through forests and over fields killing every living thing that comes their way. Few insects can escape one of these marauding armies, as they are killed by the ants if they remain on the ground or in the bushes or trees, while if they take to flight they are caught by insectivorous birds. One large and long-legged katydid, however, has acquired wisdom which enables it to escape death where others perish. This is accomplished by remaining on the ground with the body elevated as high as the long legs will permit and standing perfectly still. The ants march by the immovable stilt-like legs mistaking them for grass stems, and thus the cunning katydid escapes its ferocious foes.

Another kind of katydid under like circumstances is recorded as escaping injury by lying perfectly still. This particular kind is shaped and colored exactly like a leaf. This mimicry is so perfect that the leaf-like wings even have veins just like those of a real leaf and also transparent spots as are so often seen in leaves.

Some of these leaf-mimicking katydids are green, like living leaves, and some are brown just like dead dry leaves. There are other equally wonderful examples of mimicry in this interesting group of insects.

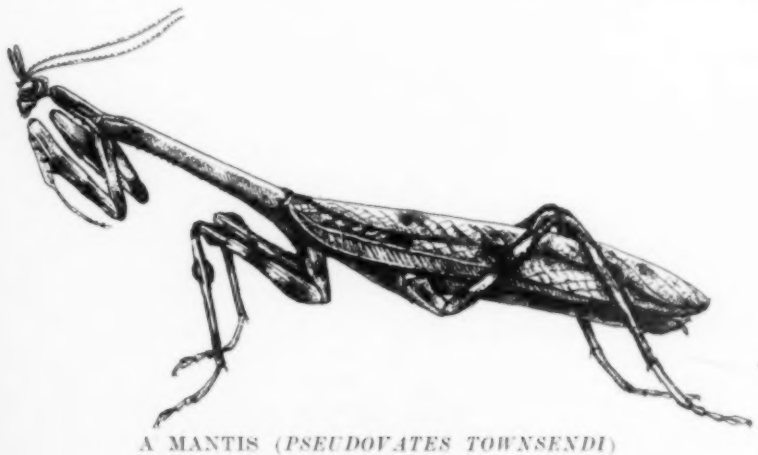
Related to the katydids we find the crickets (Gryllidae), insects well known to almost everybody. As in the case of the grasshoppers and the katydids, most of the crickets have long hind legs fitted for jumping. Like the katydids the females of most crickets have a long egg-laying organ, and the males are notable musicians.

A large African cricket (*Brachytrupes megacephalus*) is said to produce notes capable of being heard for a mile. But it is not such loud notes that have gained for crickets their reputation as musicians, it is rather the low musical tinkle of the smaller forms such as our common tree crickets. The melody of cricket trills vies with that of the notes of katydids in calling forth the approbation of the listener. In parts of Asia crickets and katydids are kept in small cages as we keep canaries, and such caged insects are commonly seen offered for sale in the public markets.



A CRICKET (*GRYLLUS ASSIMILIS*)
WITH A WIDE DISTRIBUTION IN NORTH AND SOUTH AMERICA.

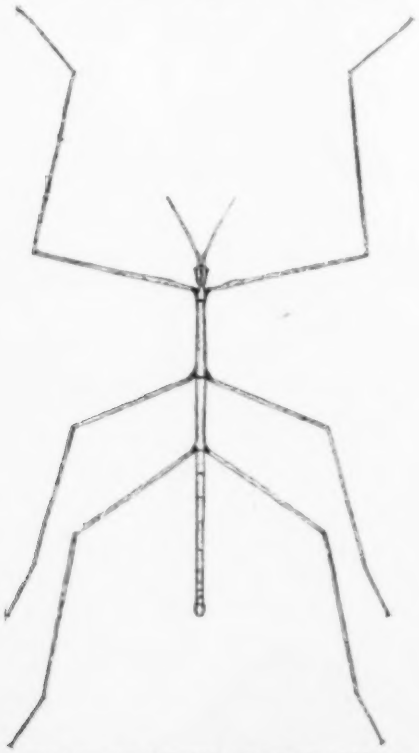
Aside from their musical accomplishments, crickets serve to amuse mankind by the display of their belligerent and pugnacious dispositions. The fighting instinct at once asserts itself when males of certain kinds are brought together. In China fighting crickets are very popular, and are cared for as carefully as we care for our race-horses. A champion cricket gladiator is said to sell for as much as fifty dollars, and large sums are



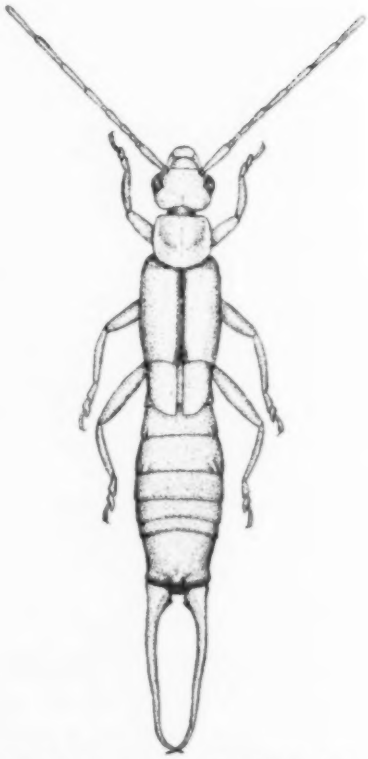
A MANTIS (*PSEUDOVATES TOWNSENDI*)
FROM MEXICO.

won and lost on the outcome of cricket fights.

While by devouring his crops the grasshoppers do the most material damage to man, there are certain relatives of these insects which are even better known as pests, especially to housewives. These are the cockroaches (Blattidae). The cockroaches do not have the hind legs adapted for jumping, like the grasshoppers, katydids and crickets. There are many kinds of roaches, especially in the warmer countries. Two kinds are especially well known and hated by the householder. These are the croton-bug or German roach, a small brown sort with two black stripes on the back behind the head, and the black roach, a larger kind in which the female is provided with much shortened wings. Other larger long-winged roaches often occur in buildings, sometimes in great numbers, but it is the two just mentioned that are most often found in homes.



A WALKING STICK (*PARABACILLUS COLORADUS*)
FROM COLORADO.



AN EARWIG (*CIPEX SCHWARZI*)
FROM CUBA.

There are three other groups of insects which are related to those previously discussed which, though quite as interesting, are of less real importance to us. These are the mantises or "rear-horses" (Mantidae), which feed on other insects, the walking sticks (Phasmidae) which are leaf-eating, and the earwigs (Forficulidae).

TOBACCO AND SCHOLARSHIP

By Dr. J. ROSSLYN EARP

ANTIOCH COLLEGE

"THE brain contains three kinds of cells: memory cells, intelligence cells and conscience cells," said my visitor. I did not deny it. After all she is a prominent official in the Anti-Tobacco League of this state. All three kinds of cells, she says, are ruined by tobacco. Yes, sir, she has seen them herself.

This little incident, extracted from a somewhat lengthy interview studded with such doctrinal gems, may serve to demonstrate how far removed is the great tobacco controversy from the ordinary paths of science. Among the innumerable articles that have been published for or against the smoking habit it is necessary to make a long and tedious search if we would discover anything of real worth.

One aspect of the subject which, not unnaturally, has attracted a good deal of serious academic interest is the relation of smoking to scholarship. Eighteen years ago E. L. Clark[1] observed a great difference in scholastic achievement between students who smoked and those who abstained. In a college of 201 men 69 per cent. of the non-smokers and only 18 per cent. of the smokers won honors in scholarship. The excellence of non-smokers in scholarship has been noted for college students by various other investigators, among them Jay W. Seaver[2] (Yale), George L. Meylan[3] (Columbia) and W. L. Holt[4] (University of Tennessee). The latter emphasizes particularly the failure of the smokers. Similar studies have been made for high-school students, the latest and most important being that of M. V. O'Shea[5] covering a large material (about 70,000 boys). There is remarkable agreement on the general conclusion that non-smokers, whether at school or in college, are better scholars. Three series of observations made at Antioch College, one in 1924, one in 1925 and one in the present year, have convinced the writer that this difference is constant and that it is statistically significant, since the difference in performance of smokers and non-smokers is of an order that could not be accounted for by chance alone. Figure 1 shows graphically how the non-smokers (continuous line) excel in high scholarship, while the smokers (interrupted line) are more numerous in the lower grades. This figure is taken from the study two years ago. The mean grades on that occasion were as follows:

	Mean Grades
177 Smokers	3.51 plus or minus .03
176 Non-smokers	3.14 plus or minus .03

Difference .37 plus or minus .04

There arises the question as to whether the tobacco causes low scholarship or whether there are one or more attributes closely correlated both with smoking and with low scholarship. Dr. Meylan believed that smokers are more idle. It might be either that the smoking habit

[1] Clark, E. L., "Effect of Smoking on Clark College Students," *Clark College Record*, 1909, IV. 91.

[2] Seaver, J. W., "The Effects of Nicotine," *The Arena*, 1897. 17. 470.

[3] Meylan, G. L., "Effects of Smoking on College Students," *Popular Science Monthly*, 1910. 77. 170.

[4] Holt, W. L., "Educational Research and Statistics," *School and Society*, 1921. 14. 136.

[5] O'Shea, M. V., "Tobacco and Mental Efficiency." New York: The Macmillan Co., 1923.

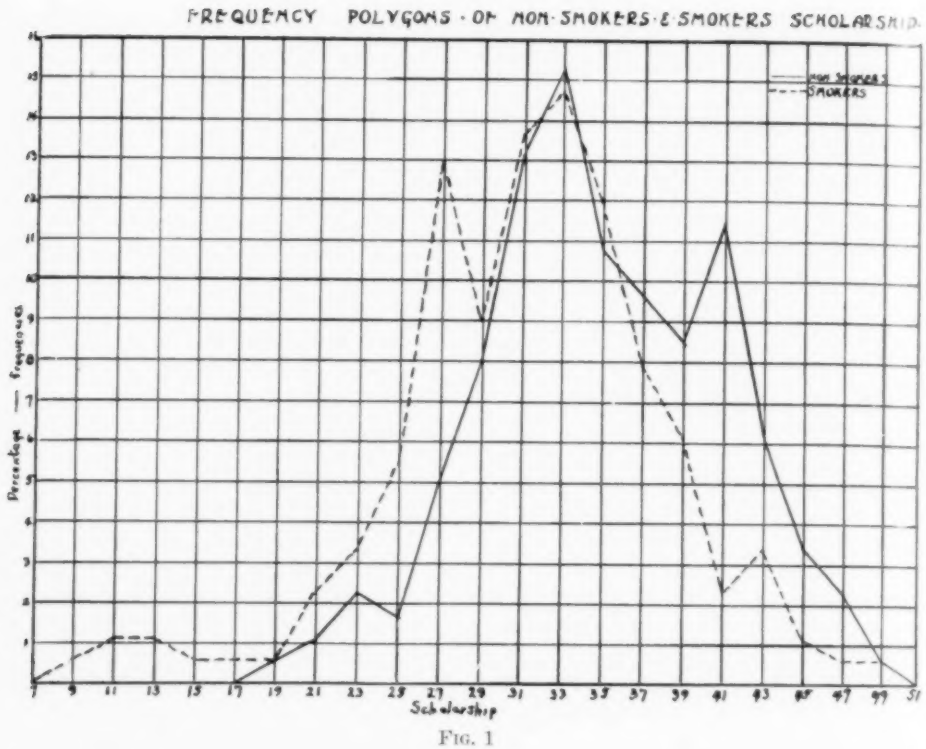


FIG. 1

induces lethargy or that lazy men are the kind that find smoking agreeable. Or again it might happen that smoking is associated with desire for social intercourse and that the gregarious instinct, turning away from solitary study, is the cause of low scholarship. Such speculations are hard to put to scientific proof. If extra-curricular activities are a test of the gregarious instinct then Antioch smokers are not more gregarious than their fellows. We have found a greater proportion of non-smokers than of smokers so occupied. This year, for example, 237 non-smokers engage in 249 extra-curricular activities while 219 smokers engage in 211. But it may well be doubted if this is a fair test.

The problem may be attacked from the other side. Is there any positive evidence that scholarship is decreased by the use of tobacco? Laboratory experiments by C. L. Hull[6] showed some loss in accuracy and in memory by the smokers at the time of smoking. The differences were not so great as to be exceedingly convincing, though the care in controlling the experiments makes them of value. In 1925 the Antioch material appeared also to afford some positive evidence of a causal relationship between tobacco and low scholarship. Among the smokers themselves we found that those who had smoked longest, those who smoked most, and those who inhaled were poorer scholars than the remaining smokers. The differences were not exceedingly significant though they were by no means negligible. This year, however, they do not appear, or if present are so small that they are not statistically valid.

[6] Hull, C. L., *Psychological Review Monograph Series* Whole Number 150, 1924, pp. 1–161.

It is worth noting, as being contrary to some previous observations, that the Antioch abstainers have no advantage in "intelligence" as measured by the Thurstone and O'Rourke tests. In fact both these tests as applied to our 1927 material give a small advantage to the smokers. This is easily explained inasmuch as the great majority of students dismissed from this college because of low scholarship are smokers. Since the smokers lose so many of their least intelligent constituents, the average "intelligence" of the remainder is naturally boosted. It is possible to argue that, but for this process of natural selection, the non-smokers would not only equal but excel the smokers in intelligence. The fact remains that it is not to "intelligence" that we must attribute the superior scholarship of our abstainers now in college.

An interesting possibility that is not very easy to explore lies in the reputed powers of smoking to stimulate or inspire day dreams. It is well known to the psychologists that day dreaming is a refuge of those who find reality too unpleasant. The medical student who can not pass his examinations may enjoy the prestige and emoluments of a specialist by no other way. Can it be that students who have difficulty in adapting themselves to the requirements of intellectual achievement turn by nature to the solace of the weed?

There is still plenty of opportunity for research on this subject. That non-smokers excel in scholarship seems to be indisputable. The reason or reasons for their excellence are still very uncertain.

A HISTORY OF COD LIVER OIL THERAPY

By T. SWANN HARDING
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THE medicinal use of cod liver oil is yet another of our modern ideas which actually reach back into very respectable antiquity for their origins. It constitutes another of those human advances that became obscured, forgotten, actually antagonized, and had later to win its way back to renewed acceptance by hard work. Humanity, like a laggard school boy, actually forgets some of its lessons amazingly easily and is often curiously averse to the process of relearning them.

It is recorded that Pliny and Hippocrates advocated the use of dolphin oil as a remedy for chronic skin eruptions, which shows that fish oil was early used for conditions somewhat similar, perhaps, to those now remedied by cod liver oil. According to "Percival's Essays"[1] cod liver oil had in 1790 long been an invalid food in Scotland and the Isle of Shetland. It was also used at the Manchester Infirmary (England), both internally and externally, to remedy so-called "rheumatism" as early as 1789; at that time this one infirmary was using a hogshead of cod liver oil annually!

In 1807 Bardsley speaks of using cod liver oil effectively on women patients worn out by "rheumatic" attacks (probably due to a depletion of calcium from their bones) after pregnancy. To-day, when we know so many more nice long words, this condition would probably be called "osteomalacia."

A physician named Bennett[2] had actually to revive the use of cod liver oil in 1841, it having fallen into almost complete disrepute. In Holland cod liver oil had long been used specifically for rickets, a disease caused by imperfect deposition of calcium in the bones, and the Utrecht Society of Arts made cod liver oil therapy the subject of a prize essay in 1822. Schenck published the first German article on the use of cod liver oil in 1822.[3] He used it in gout and "rheumatism." But it is 1824 before the record shows the specific use of cod liver oil to cure rickets.[4] It was then used successfully on children of from three to five years of age and soon spread into universal use in Germany.

In 1837, M. Roche communicated to the Société de Médecine de Paris a paper describing the use of cod liver oil in rickets by Dr. Bretonneau. An article of similar import, by one Villard, appeared also in 1836.[5] In each case, be it noted, fishermen had first used the oil empirically on their children and physicians accidentally came upon the matter and gave it wider application.

Now in spite of all this cod liver oil fell into disuse. In the late nineteenth and early twentieth century its specific use to cure rickets had been entirely forgotten. It was often spoken of as a remedy in tuberculosis or even in rickets, but it was regarded merely as a general tonic, easily digested and assimilated, yet not specific. True, no one had ever known that vitamins, and not its rich fat, made it valuable, but it had found specific use in rickets.

For instance, Hare[6] recommended cod liver oil among other "general tonics" and indicated its use, among other

[1] 4 Ed., Vol. II, pg. 360, 1790.

[2] "Treatise on the Oleo Jecoris Aselli," Edinburgh, 1848.

[3] *J. d. Pract. Heilk*, 55, 31, pt. 6.

[4] Shiitte, *Arch. f. Med. Erfahrung*, 79.

[5] Schmidt's *Jahrb.*, 5, 147.

[6] "Practical Therapeutics," Ed. 13, 1909.

things, for rickets. Henoch,[7] a famous children's specialist, at times felt almost convinced of the real value of cod liver oil in rickets but most of the time seriously doubted its efficacy. Rotch,[8] another child specialist, did not even mention cod liver oil in ricket therapy. M. F. Still,[9] yet another, flatly declares that cod liver oil has no specific value in any disease and while other writers on children's diseases casually advised its use[10] it was not much used.

From 1908 to 1912 a prominent German investigator named Schabad sought very hard, against considerable acrimonious opposition, to prove that cod liver oil, unlike other oils, was of specific value in the treatment of rickets. In 1910 cod liver oil therapy was spoken of as struggling to overcome scientific skepticism, but it was added that pharmacologists and physicians generally distrusted its specific value.[11] As late as 1913 a French research worker[12] "proved" that the therapeutic action of cod liver oil depended upon the fact that it increased the bodily utilization of protein.

It was actually in 1916 that the celebrated Polish investigator who was a pioneer on vitamins, Casimir Funk, suggested tentatively that vitamins might be accountable for the efficacy of cod liver oil in promoting normal bone growth. Then Dr. Alan Brown and coworkers[13] in 1920 found that the administration of cod liver oil to rachitic children definitely increased the calcium content of their blood. Then came E. V. McCollum.

Until now other substances had been known to be useful in rickets, but none seemed so efficacious as cod liver oil. Actually two vitamins were involved where only one was assumed to be present; these two are called fat soluble A and D. McCollum began to publish a stream of articles on vitamin therapy, describing the use of cod liver oil in the prevention of rickets in 1921.[14] He first produced experimental rickets in animals and then cured it by the administration of cod liver oil.

He became suspicious that cod liver oil differed basically from such things as butter fat because, while both demonstrably contained large amounts of vitamin A, which controls growth, the former cured rickets and the latter would not. He finally announced that rickets prevention was accomplished by the second fat soluble vitamin, which he called D. Thus spinach is very high in A and lacks D; butter fat is high in A and low in D; cod liver oil is high in both. Therefore the latter alone, of these foods, can both cause normal growth and prevent rickets.

A lack of vitamin A, besides stunting growth, also causes susceptibility to eye, ear, sinus and lung infections; a lack of D causes rickets. But to prevent rickets properly calcium and phosphorus must both also be in the food in correct proportion to each other for easy bone building by the body. They occur so in milk. Milk, however, is low in vitamins. Its vitamin content is perhaps more important than its butter fat content, now used as a standard of value. Milk will become very potent in vitamin D, as will many other foods, if irradiated with (exposed to through a quartz but *not* a glass plate) ultra-violet light. It may also be rendered higher in vitamins A and D by proper feeding of the cow on fresh greens and its exposure to sun

[7] "Lectures on Children's Diseases," 1889.

[8] *Pediatrics*, Philadelphia and London, 1901.

[9] "Common Diseases of Childhood," London, 1912.

[10] Meiggs, Pepper, 1886; Starr, 1894; Holt, 1896; Kerley, 1907; Fischer, 1907.

[11] Rosenstern, *Berl. Klin. Wochenschr.*, 47, 822.

[12] Maignon, *Comp. Rend. Soc. Biol.*, 72, 1054.

[13] *American Journal Diseases of Children*, 19, 413.

[14] *The Journal of Biological Chemistry*, 45, 333–348.

or to ultra-violet light. Or it may be used for its minerals and the vitamin deficiency made up with cod liver oil.

After McCollum things happened rapidly. In 1923 it was shown[15] that the calcium of the blood varies very little from animal to animal of the same species. Eating calcium salts or their injection will at most cause but a temporary rise in blood calcium. But there is a chronically low blood phosphate in rickets and in some cases of kidney trouble. Various diets were fed, deficient in calcium or in phosphorus, and rickets always developed, but it could readily be cured by cod liver oil, and it was observed that in such cases the blood calcium also rose to normal.

In 1924 *The Journal of the American Medical Association*[16] made this statement editorially:

> It is an extraordinary circumstance, as was recently remarked, that a substance containing neither calcium nor phosphorus when administered to an animal whose blood is deficient in these elements should have the power to cause the calcium or the phosphorus, as the case may be, to rise to, or nearly to, the level commonly regarded as normal and thereby to establish the normal equilibrium. Furthermore, the cod liver oil not only acts as a regulator of the calcium and phosphorus metabolism (use by the body), but also permits the organism to operate with greatly increased economy. In the presence of calcium or phosphorus starvation cod liver oil enables the animal to get along as if the calcium or the phosphorus were supplied in sufficient or almost sufficient quantity in the diet. It is necessary to suppose that cod liver oil brings about maximal utilization of the minimal quantity of calcium or phosphorus in the diet. It greatly reduces waste of these elements and, therefore, must bring about a maximal absorption from the alimentary tract.

This is the case for cod liver oil therapy stated authoritatively but in simple language.

The statement does not stand altogether unchallenged because certain workers[17] claim that the addition of cod liver oil to a diet really deficient in calcium will not raise the percentage of calcium in an animal's body. They declare that some salt of calcium, like calcium lactate, must be fed to accomplish this. But vitamin D does control the successful utilization of calcium by the body.

Cod liver oil retains this efficacy remarkably. It may be stored many months and still remain potent.[18] Furthermore, feeding cod liver oil or irradiating with ultra-violet light will increase the number of eggs chickens lay and will also increase their hatchability.[19] This is directly related to the amount of calcium in the body of the chicken embryo, it being increased when light and cod liver oil are used.

When giving milk, cows and goats tend to lose large amounts of calcium from their bodies because the milk contains so much. This loss may be prevented in goats by exposing the animals to ultra-violet light for a few minutes daily.[20] Sunlight seems thus more important to the animal than green plant food. It would seem that cod liver oil might also be useful here, but when cows were fed cod liver oil they did not respond as they did to light, but continued to lose calcium during lactation.[21]

It was observed above that the vitamins in milk may be increased by properly feeding the cow. English investigators have worked on this. At first they had the two vitamins A and D mixed up, as every one else did. But ultimately they showed that the amount

[15] Park, E. A., Guy, Ruth A., Powers, G. F., *American Journal Diseases of Children*, August, 1923, 26, 103.

[16] Vol. 83, pg. 1169.

[17] Sherman and McLeod, *J. Biol. Chem.*, lxiv, 429, 1925.

[18] Hart, Steenbock, Lepkovsky, *J. Biol. Chem.*, lxv, 1925, pg. 571.

[19] Hart *et al*, *Jour. Biol. Chem.*, lxv, 579, 1925.

[20] Hart *et al*, *Jour. Biol. Chem.*, LXII, 117, 1924.

[21] Meigs *et al*, *J. Agricultural Research*, 32, 833.

of vitamin A in milk depends on the cow's food and is unrelated to its exposure to light, while the amount of vitamin D depends upon whether the animal is or is not exposed to sunlight. As a whole, then, a cow on green pasturage will give the best milk from the vitamin standpoint.[22]

The application of this idea to a nursing woman followed not long after.[23] It was shown that if a nursing woman were exposed to ultra-violet light for a few minutes daily her milk became very potent in the rickets-preventing vitamin. While the milk would not cure rickets in rats when the woman was not exposed to the light, it cured the rickets readily when she was exposed.

Vitamin D, which occurs in cod liver oil, can, it seems, be produced from certain fats by their exposure to light. There is a human fat named "cholesterol" which occurs widely distributed near the skin. It has been shown that if this fat is exposed to ultra-violet light, or to sunlight, some of it is transformed into vitamin D by that exposure.[24]

This exposure does not take long. In fact it must not take too long. If it is permitted to go beyond a certain point the vitamin D is destroyed again. Cholesterol normally contains no vitamin D whatever; it will not cure rickets. But expose it to the ultra-violet rays from a mercury vapor lamp for one hour at a distance of eighteen inches and five per cent. of it will become a crude oil which is extremely high in vitamin D, protective against rickets; the rest of the cholesterol will still contain no vitamin D. More recently it has been held that absolutely pure cholesterol will not produce vitamin D and that some impurity is involved,[25] but the fact remains that vitamin D is produced by exposure to light and it has even been shown that the Coolidge high voltage cathode rays (so widely bespoken in the press a short while ago) will activate cholesterol in a similar manner. But exposure of an experimental animal to these rays is not a success because the animal can not stand such rigorous treatment and remain alive.

This brief outline of the history of cod liver oil therapy has demonstrated that the substance was given medicinally quite a long while ago as a specific for rickets, but that this use was forgotten and the oil remained merely one of the general tonics to be used empirically for debilities of all sorts. Later it fought its way back to recognition as a specific for rickets. Speculation began as to the reason for its potency and, after a period of crediting its nourishing qualities, it began to be supposed that the oil contained vitamins. Ultimately this hypothesis proved correct and it was found that ultra-violet light would impart similar properties to other oils and fats which were normally quite inert from the vitamin standpoint. To-day ultra-violet irradiation and cod liver oil are both used to cure rickets, but the latter is recognized as more effective and is firmly established as a specific therapeutic agent.

[22] Luce, *Biochem. Jour.*, 18, 716, 1229; 1924: Chick, Roscoe, Luce, *Biochem. Jour.*, 20, 632, 1926.

[23] Hess, Weinstock, Sherman, *Jour. Amer. Med. Assoc.*, 8824, January 1, 1927.

[24] Rosenheim and Webster, *Biochem. Jour.*, 29, 537, 1926; Hess and Shear, Kramer and Shelling, *Jour. Biol. Chem.*, 71, 127, 213, 221, 1926.

[25] Hess, *Proc. Soc. Exp. Biol. and Med.*, 24, 369, 1927.

A HISTORICAL SKETCH OF THE RELATIONSHIP BETWEEN HISTORY AND SCIENCE

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THE relations between history and science seem not to have been hitherto at all close. It is true that the Greek word, historia, might indicate any investigation of the past, of the present or of nature, and that this usage persisted into the middle ages when in Latin anatomical manuscripts of the twelfth and thirteenth centuries one finds a "history of incisions," a "history of arteries," a "history of muscles" and a "history of nerves." It is true that before the present age of specialization a single person was more likely to deal with several fields of knowledge or research. But the number of those whom we know to have been productive in both history and science is not very impressive, partly perhaps because their writings in the one field or the other have been lost. Those who have engaged in both the historical and scientific fields of activity have often kept them in separate compartments rather than effected a happy union between them, and have not necessarily been led either to a historical view of science or a scientific method in history. Calendars have developed into fasti and annals, and chronologists have often been men of some mathematical or astronomical attainments. The same writers were apt to retail historical anecdotes and yarns concerning animals and other marvels of nature: witness Aelian of Praeneste and the Deipnosophists of Athenaeus. Encyclopedists comprised the phenomena of nature and the story of man along with everything else in their loose collections. But such associations are not very impressive. When scientific matter has been introduced into a history in the past, it has usually been in the nature of a digression.

Dr. Sarton begins the first volume of his recent monumental "Introduction to the History of Science" with Homer, but as my time is somewhat limited, I will pass on immediately to Herodotus, once regarded as the father of history. His epic or dramatic variety of history, largely personal in his first book, in the following survey of the lands of the Near East strews before us a number of valuable bits of scientific or pseudo-scientific lore. But it may be questioned if the Ionian philosophers with their world grounds and evolutionary theories, their scientific curiosity concerning the past, did not approach closer to a true combination of history and science than either he or Thucydides, whose critical and sophistical treatment brought history into closer relation to the theoretical science of the day. And this raises the query whether history shall appeal primarily to the human interest motive, as in Herodotus, or be limited largely to past or even recent politics, as in Thucydides and so much recent American teaching of it, or whether it shall survey the entire past with a scientific purpose and method and with especial emphasis upon the past of those intellectual faculties and that mental life which distinguish man from other living beings and from other objects of scientific investigation.

The ancient Greek who best combined the historical and scientific interests appears to have been Aristotle. It is true that the notion which he handed on

of science as concerned only with eternal and unchanging truth leaves little room for history. But he wrote a History of Animals, a Constitutional History of Athens, and treated of both the development of Greek literature and the views of philosophers before him. His medieval and early modern influence, however, was far more as a philosopher and a natural scientist than as a historian.

In the Hellenistic period which followed Aristotle, the bookish compilation in libraries of histories from previous histories became largely disassociated from the study of anatomy, astronomy, botany, physiology, and the like; which, while also too inclined to repeat past authors' opinions, seem to have maintained more contact with reality.

With Pliny the Elder, however, in the Roman Empire we come to a man who in his Historia Naturalis dealt with science for the most part historically. While he can not be said to have dealt with the past scientifically, he is none the less after Aristotle our outstanding example in antiquity of the union of history and science; and he was until then and for long to come the chief historian of civilization. His vast influence in medieval and early modern times was in the main conservative, anchoring science to previous lore and attaching the ball and chain of past superstition to the winged ankles of Mercury.

The Bible is stronger on its historical than its scientific side, and the same was naturally true of early Christian thought and writing. History was now reviewed and reconstructed as the working out of a divine plan and purpose, but while we have a sort of Christian Pliny in the encyclopedist and chronologist, Julius Africanus, and while such works as the Hexaemeron of Basil cater to an obvious curiosity concerning nature, this apparently existed in the audience more than in the preacher. Christianity has often been called a great historical religion, but until Mrs. Eddy it was seldom accused of being a great scientific religion. The Schoolmen and medieval theologians nevertheless attempted with the aid of Aristotle to make it such, and to correlate and reconcile Trinity with First Cause, angels with spheres, miracle with natural law and marvel, and, in general, traditional supernaturalism with a rational theory of the universe. The effort to establish this bold synthesis for centuries absorbed many of the most advanced thinkers of the medieval universities, but was already in the fourteenth century questioned by some of the ablest minds among them, was later attacked by humanists and religious reformers, and finally was generally abandoned by an indolent and dilettante early modern society. The study and writing of history at no time had much relation to it, except that the stress laid upon authorities reminds one of historical method. But we must turn back again to the earlier Moslem world.

The wide sweep of Arabian conquest, embracing three continents and joining such distant lands as Spain and Persia in the communion of the same language, promoted a cosmopolitanism and internationalism favorable to the development of history and science side by side. Despite nomadism and fanaticism, travel and study gave breadth of view and insight. It is true that we can no longer regard the Arabic speaking and writing world as the sole channel by which an interest in science flowed first to the later medieval, and then, augmented by a supposed revival of classical science, to the modern world. We now realize that there was always some interest in science during the early middle ages both in the Byzantine Empire and the Latin West, and that the renaissance of the twelfth and thirteenth centuries, far more important scientifically than the later so-called classical Renaissance, was not due merely to translations from the Arabic. At the same time there was much more scientific writing done in Arabic than in any other language from the seventh to the eleventh century.

This Arabic science, like so much of ancient, medieval and early modern science, was mingled with superstition and magic, but was also often marked by rational skepticism and experimental method. It appears to have had much greater effect upon the West than did the Arabic historiography. But for the combination in an Arabic writer of the interest in history and science with a rational attitude one may refer the English reader to the works of Albiruni on India and the Chronology of Ancient Nations, both available in translation.

We have just referred to superstition and magic. The pseudo-science of astrology, whose origins have not yet been satisfactorily established but which at least existed in a highly developed form by the Hellenistic and Roman periods, was still further elaborated by writers in Arabic such as Albumasar, and continued upon the same basis into late medieval and early modern times in the West, while it of course still affects all Oriental peoples. Astrology had important relations both to history and to science. Not only were all properties of plants, stones and animals referred to the planets and signs, and the formation and medical treatment of the human body placed likewise under their influence, but we also find the astrological interpretation of history as in the treatise of Alkindi, "the first and only great philosopher of the Arab race," on the duration of the Arabian Empire, or in the theory of great conjunctions of the superior planets as marking transitions and periods in history. Comets and eclipses, too, were no mere natural phenomena but related to the course of human history. Rulers assiduously consulted astrologers; it was important to know the particular constellations under whose influence a given region lay; the date of the founding of a city was as significant as the horoscope of an individual; and annually, at least in fifteenth century Italy, elaborate forecasts of the probable course of events—natural, social, and political—during the coming year or for each of its four seasons, were issued not by half-educated impostors but by university professors. Never in all probability have history and science been in such close relationship as they were supposed to be brought by astrology.

One reason why Arabic historiography made less impression on the West than Arabic science may be that already in the tenth and eleventh centuries there were several remarkable historians in the Latin world with whom Gerbert can alone be compared in the realm of Latin science, and he, by virtue of his informing letters, was a bit of a historian too. Since the medieval Latin revival of learning in the twelfth and thirteenth centuries there has been a continuous development of science to the present time. In the fourteenth century we have significant criticism and amendment of the Aristotelian physics; in the fourteenth and fifteenth centuries much activity in medicine and astronomy, experimental method in anatomy and surgery. Science to-day would not stand so firm if it did not have these deep foundations. This scientific development seems by and large to have been only slightly affected one way or the other by such historical movements as the so-called Italian Renaissance or humanism, and the Protestant and Catholic Reformations.

The historical writing of the time was more susceptible to their influence. The humanists, who took rather more interest in history than in science, understood classical history and writers better than most of their medieval predecessors had, but this did not necessarily make them better historians or scientists. They were too prone to imitate Livy, to take some such barren subject as The Carthaginian Domination of Spain before the Punic Wars. And they ceased to understand the middle ages. Not all historians of the fifteenth and sixteenth centuries were humanists fortunately, but the disparagement of the medieval period became general and has been

usually retained by men of science to this day. A well-balanced estimate of the past was further rendered difficult by the partisanship of Catholic and Protestant historical writers. Their researches, it is true, led them back to the medieval as well as to the early Christian period, but had the regrettable outcome that medieval history was long regarded as a field practically identical with church history.

Meanwhile, however, literary and archeological erudition and textual criticism, aided by the invention of printing, had been making steady strides forward and led to the gradual formulation of something approaching scientific method in historical investigation. Greater toleration and freedom from religious bias also came as a reaction from the Reformation and Wars of Religion. In the course of the seventeenth and eighteenth centuries both history and science also abandoned the astrological point of view. But the Biblical account of pre-Greek history still held the field practically unchallenged in the skeptical eighteenth century of the French Encyclopédie and Voltaire. Sir Isaac Newton, for example, was a very sorry historian who tried to fit ancient history to the Procrustean bed of Biblical chronology. Some of the great German philosophers of the eighteenth and early nineteenth century engaged in scientific investigation of a sort, and they almost all had their philosophies of history, but I do not know that there was much connection between these two activities.

But in the meantime the progress of erudition had given rise to histories of learning, of the universities which reached back into the middle ages, and to collections of Scriptores. There was almost a craze for writing the biographies and bibliographies of all the illustrious men, and especially the writers, who had been connected with a given city or religious order or university. These histories were much alike and used the works of their predecessors a great deal, but at least they contain materials or suggestions for the history of science. I mention them for the further reason, however, that historians to-day may be in danger of continuing somewhat the same bookish scholasticism. To a considerable extent historical scholarship of the nineteenth and twentieth centuries has simply followed along and broadened out paths that were laid down in the sixteenth, seventeenth and eighteenth centuries. The much vaunted Monumenta Germaniae Historica are after all but a more critical and greatly enlarged sequel to many such preceding efforts: Chevalier is only a digest of the kind of works just mentioned.

Much of this is of course inevitable. Yet if the historian is to arrive at results at all comparable to those of the scientists, he must be original and fertile in his mode of approach, not merely accurate and faithful. Has history yet had its Galileo or Harvey or Newton or Linnaeus or Darwin or Einstein? On the other hand, it must be confessed that the great advance of science has been due even more to the invention of mechanical aids such as the mariner's compass, the barometer, the accurate time piece, the microscope and the telescope, photography, than to the ideas of such individuals. Can history hope for the devisal of such facilitations in method, each opening a whole new world as it were or side of human life to the examining eye? Archeological discovery of the past century and recent years may be said to have had such an effect, extending our vista as far back in time as the telescope has carried it on into space, and to have appealed almost alike to historians and to men of science. Geology and biology alone would hardly have carried the day for evolution without it. Advocates of the New History believe that recent science and thought offer other instruments which may prove almost equally efficacious in extending, correcting, or substantiating our previous knowledge and evaluation of the human past.

THE GASTRONOMY OF COLONEL CARTER OF CARTERSVILLE

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MUCH of the social, political and intellectual life of the people clustered about the banquets of Babylon, the festivals of Greece, the feasts of Rome and the coffee houses of England, but all these lacked the wholesomeness, the hospitality and the charm of a dinner of a Virginia manor in those happy days often designated as "befo' de wah." Belshazzar's table had luster, Epicurus gave eating fastidiousness, Lucullus prided himself upon the costliness of his cuisine, and Boswell learned his Johnson in the taverns of London, but only a Colonel Carter of Cartersville could make a dining room so inviting and the food so physiologically exact that the guests "wanted life made up of one long dinner continuously served."

If correct eating is the realization of an indefinable satisfaction and is the procurement of adequate nutrition through the gratification of the appetite, their attainment depends not only upon the combining of pleasure with the routine of bodily nourishment, but upon the wise choice of food, finesse in its preparation, the attractiveness of its serving and the creation of an atmosphere psychologically proper to stimulate functions essential to normal digestion. In each of these fields, Colonel Carter was a connoisseur without a peer.

The colonel was a native of Fairfax County and of one of the "vehy fust families of Virginia." He was frank, generous, tender-hearted and as simple as genuine. He had a soft, low voice, tempered with a most attractive cadence. He possessed a fair education and considerable knowledge of men and of the world. "He was proud of his ancestry, of his state and of himself. To share with you his last crust was a part of his religion; to eat alone, a crime."

He had more than the genius of an epicure, he had inherited the instinct to dine well. To him a good dinner was the necessary preliminary to all the important duties of life—the pièce de résistance of social intercourse. The head of his table was his throne. There he ruled supreme with a splendor and a charm that reflected the varied hues of the many sides of his delightful nature. It is not surprising that such a host should portray in his dinners the commingling of the exactness of science, the emotions of an artist, the chivalry of a knight and the cordiality of a Southern gentleman of the old school.

Although the colonel fell upon evil days financially following the Civil War, it did not dull his keen appreciation of the relation of attractive surroundings to eating and digestion. He, accordingly, selected the finish and the furniture of his dining room to focus the stimulating effect of a delightful environment upon the dining table.

The room presented a charming interior, and a remarkable appearance of coziness and restfulness. An open fireplace added its cheerfulness, while an English grate set into the chimney offered convenient facilities for the production of the brews and mixtures for which the colonel was justly famous. An unpretentious sideboard, some easy chairs, a pair of silver candelabra on the mantel and a few borrowed etchings and sketches made the table, which occupied

the center of the room midway between the fireplace and the grate, the one object to fix the attention.

It was covered with a snow-white cloth resplendent in old India blue which matched the plates warming by the hearth. In its center was a great dish of white crisp celery and at either end a pair of coasters—one holding a cut-glass decanter of Madeira; the other, awaiting its customary bottle of claret.

In these modest surroundings, Colonel Carter, by his knowledge of food, the warmth of his hospitality and by his extraordinary personality, converted a meal into the classic of a Virginia dinner, putting into practice gastronomical principles which anticipated certain discoveries of modern science by several decades.

The colonel promoted the hygiene of nutrition by the regularity of his meals and by his insistence upon the punctuality of his guests. To be ten minutes late to dinner was almost unpardonable, because a duck could not be cooked "a minute over eighteen" and "the burning of a canvasback was a crime." To him all food had its exact minute of cooking and precise temperature for serving. Such scientific accuracy excluded dilatory diners.

He gave prestige and social correctness to his dinners by always dressing especially for them. Chad, the waiter, emulated the example of his master and appeared brilliant in white jacket and apron. He took his position behind the colonel's chair and with great dignity announced that dinner was served.

The colonel immediately said the blessing—"an old custom of my ancestors which I never omit." Dinner was an occasion of fellowship and vivacity; business was adjourned—"not a word befo'" the meal was finished.

Worry and haste, the twin brothers of dyspepsia, never passed the threshold of his dining room. Its arrangement and his companionship immediately gave his guests comfortable relaxed bodies, free and easy minds and cheerful happy spirits. Nothing, not even an impending duel, could impair his appetite or dull the colonel's enjoyment at dinner.

"Throughout the entire repast he was in his gayest mood, brimming over with anecdotes and personal reminiscences, and full of rose-colored plans for the future." His conversation would range from the preparation of pickles to politics; from family blood to 'possum hunts; from domestic delicacies to modern literature. His talk was as delightful as potent in the production of an excellent mental attitude for normal digestion.

Lest some sorrow or disappointment hidden behind the smiling countenance of a guest should suddenly emerge to mar the joy of dinner, the genial colonel would admonish his hearers: "Salt yo' food, suh, with humor. Season it with wit, and sprinkle it all over with the charm of good fellowship, but never poison it with the cares of yo' life. It is an insult to your digestion, besides bein', suh, a mark of bad breedin'."

No fiat of preventive medicine needs more an Elijah and a modern Carmel from which he might proclaim it than: care, speed and food-bolting wreck health. More and more is the meal time being robbed of its restfulness, its cheerfulness and charm, by becoming a business conference and the zero hour for launching drives. How futilely does the busy man of to-day sacrifice pleasure, mastication and time for eating—the essential of normal digestion—only to find that he can not escape the consequences of his folly by swallowing pills, potions and powders.

Unwittingly, Colonel Carter seems to have employed every physiological method to accelerate and to intensify the appetite through an appeal both to the psyche and to the sensorium. By subtle suggestion through his delicate cautions to Chad, his cook, in the pres-

ence of his guests, he used their eyes and ears to convey powerful psychological stimuli to create the desire for food and to produce conditions favorable to digestion.

An excellent example of his methods, though unconsciously performed, to prepare the minds of his guests for dinner, is well illustrated in his directions for the cooking and serving of canvasback duck.

"Not a minute over eighteen, Chad. . . . Lay 'em here [head of table], Chad —right under my nose. Now hand me the pile of plates sizzling hot and give me the carving knife a turn or two across the hearth."

(To one of the guests) "Major, see the blood, suh, follow the knife."

Chad: "Suit yo', Marsa?"

Colonel: "To a turn, Chad."

Like an artist mixing his pigments to give his portrait the right effect in high lights, gradations and shadows, the colonel compounded sweet, sour, salt and bitter with a master's skill to produce an exquisite taste. "A drop of sherry," "a dash of bitters," "the juice of a lemon," "a pinch of salt," "a dust of cayenne" and "smothered in sweets" were used to prepare the palate for the kind of food "they raise, gentlemen, down my way."

Food fit for a dinner at the colonel's must not only have a delicious taste and "send a savoury cloud of incense to the ceiling," but each article to be palatable must be cooked to the minute—neither more nor less—and even the temperature of the claret was "lovingly tested by the palms of the hands."

As a landscape painter in picturing a scene looks beyond his canvas to the myriad-tinted woodland, the meadow with its meandering stream and to the sunset glow, so the colonel in preparing a dinner saw his ducks diving for wild celery in the bleakness of winter and his venison feeding upon sugar maple. Artist-like he put his vision of nature into his masterpiece—a Virginia dinner.

"There, Major," said the colonel, as Chad laid the smoking plate before me, "is the breast of a bird that fo' days ago was divin' for wild celery within fo'ty miles of Carter Hall."

"No jelly, Colonel?" said Fitz.

"Jelly? No, suh, not a suspicion of it. A pinch of salt, a dust of cayenne, then shut yo' eyes and mouth and don't open them 'cept for a drop of good red wine. It is the salt marsh in the early mornin' you are tastin', suh—not molasses candy."

"But you use it on venison?" argued Fitz.

"Venison is different, suh. That game lives on moose buds, the soft inner bark of the sugar maple and the tufts of sweet grass. There is propriety and justice in his endin' his days smothered in sweets. But the wild duck, suh, is bawn of the salt ice, braves the storm and lives a life of peril and hardship. You do not degrade a' oyster, a soft shell crab or a clam with confectionery; why a canvasback duck?"

Whether it was in serving diamond-back terrapin, so famous in the early banquets of Maryland and Virginia; the canvasback duck, the most delicious of wild fowl; venison, clam or oyster; the fundamental principles of the colonel's epicureanism are clearest when presented in the words of the inimitable Chad, "You got to know 'em fust to eat 'em." To prepare food without proper consideration of its source and characteristics in its native state was "scand'lous." To season it incorrectly or to dress it in inappropriate trimmings was likely to be followed by dire consequences, as certified by both the master and his cook.

In a protest against the use of jelly on duck, the colonel remarks disapprovingly, "You Nawtherners don't really treat a canvasback with any degree of respect. You ought never to come into his presence when he lies in state without takin' off yo' hats. That may be one

reason why he skips over the Nawthern States when he takes his annual fall outin'."

Chad was almost as hopelessly epicurean as his master and was equally as sensitive to unsuitable preparation of food. "Tar'pin jes like crab, Major," said Chad, dropping a spoonful of butter, the juice of a lemon and a pinch of salt into the impromptu dish (shell). "Now, Major, take yo' fork and pick out all dat black meat an' dip it into the sauce an' wid ebery mou'ful take one o' dem little yellow eggs. Dat's de way to eat tarpin. Dis yer stewin' him up in pote wine is scand'lous. Can't taste nuffin but de wine. But dat's tar'pin."

Dinner, in accordance with convention, began with soup—not an insipid, mock concoction vaguely suggestive of something or other—but soup, capable of whetting the appetite and starting the digestive juices. It was served hot in a covered tureen which was placed in front of the colonel. When the lid was removed it sent "a savoury cloud of incense to the ceiling," which caused the tongues of the guests to tingle as they awaited its ladling and serving with suppressed impatience.

Following the soup, there was boiled fish fringed by slices of hard boiled eggs and "ovaled by a hedge of parsley and supplemented by a pyramid of potatoes with their jackets as ragged as tramps. Then a ham, brown and crisp, and bristling all over with cloves." Finally, the canvasback ducks, cooked to the exactness of the minute and to the precision of a turn. These, the crisp white celery, the usual accessories, the Madeira and claret in the coasters, and dinner was completed except for a pipe of "Virginia tobacco, suh—raised at Cartersville—cured by own servants. . . . Every breath of it is a nosegay."

At the end of the war, Colonel Carter was able to keep Carter Hall in his family, only by mortgaging half of his estate to his aunt. He went to New York in the hope of recouping his fortune and of returning to restore his ancestral home to some of the grandeur that once made it the center of the life of Cartersville. It was during his sojourn in the north that the dinners were given that made this chevalier of Virginia a celebrity in the domain of gastronomy. These repasts were mere reflections—miniatures of those when Carter Hall was in flower.

The belief that coal might be found on the manor at Cartersville suddenly one evening brought the colonel, engineers, financiers and Chad to Carter Hall. Next morning Aunt Nancy served a true southern breakfast for the guests in the dining room permeated with the fragrance of roses and on a table sprinkled with them. "Such a breakfast! The outpourings of a Virginia kitchen, with the table showered with roses and the great urn singing and smoking, and the relays of waffles and cornbread and broiled chicken; all in the old-fashioned dining room with its high wainscoting, spindle-legged sideboards, and deep window seats; the long moon-faced clock in the corner and the rest of it. After that the quiet smoke under the vine-covered portico with the view towards Cartersville."

In the setting of this breakfast is also to be found the beauty, the romance, the hospitality and the abundance—the elements of the gastronomy of her nephew. The day begun so propitiously, ended even more so. Coal was discovered—"a bed of bituminous, clear down to China."

Colonel Carter was now wealthy beyond his brightest anticipation. Carter Hall was to be restored to some of its pristine glory as the center of the life of Cartersville. He was to ascend again his throne at the head of his table amid the beauty and fragrance of roses to reign as the most hospitable of hosts, as a gastronomist incomparable and as the connoisseur of food par excellence.

PSYCHOLOGY AND MANAGEMENT

By Professor FRANK T. CARLTON
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MEN in all walks of life have a sharp hunger for approval and a corresponding distaste for whatever tends toward scorn, ridicule or inferiority. Each human being craves a recognition of his own individuality. The consciousness of power is sweet to the great majority. Some like the pomp and publicity which accompanies the exercise of authority; others are willing to be "the power behind the throne"—to be the invisible government. The captains of industry and labor leaders have usually been self-assertive men. Publicity, "the thrill of prestige and fame," possesses great attractions for all except a few choice souls. Men in subordinate positions, in the great drab rank and file, compensate for their lack of power and prestige by swaggering and boasting. Speeders, pace-setters and fast men gloat over their fellow-workers. If the chance of beating one's competitor is excellent, rivalry spurs one to make an additional effort. Prizes, publicity in the company paper, ratings and the like stimulate wage workers—and others. Industrial democracy, like political democracy, possesses an appeal to the instinct of self-assertion.

The small boy likes to boast of his own strength and achievements, and of the courage of his father. Mature men who have achieved little of success are prone to allude to their prowess in the past. Man, no matter what his station in life may be, loves to recount to an admiring group his remarkable achievements during the day. We love inequality and privilege provided the cards are stacked in our favor. The fraternal organization with its Grand High Potentate and its lesser lights, caters to this instinct. The desire to get one's name in the paper is by no means uncommon. Much of the popularity of games such as football, grows directly out of the popularity and publicity gained by the players. Certain varieties of "conspicuous consumption" are indulged in chiefly to indicate the spending capacity and, hence, the income and presumably the worth of the spender or of the spender's family. The idler and the worker, the professional man and the mechanic, the rich and the poor, and the young and the old, are in varying degrees affected by this primal impulse. Content and zest in industry go out of the door when little or no opportunity is offered for the nourishment of this impulse.

On the other hand, no one likes to be classified as a cog, a number or a commodity. To be treated as insignificant is distasteful. To feel that one is of little consequence and near to the "zero of insignificance," runs directly counter to deep-seated and persistent impulses and instincts. It is especially pleasing to have others recognize our importance and significance. Forces which develop within the worker a feeling that he is being belittled or degraded make for unrest and suspicion. One of the potent reasons for opposition to the introduction of machinery and more recently to the development of scientific management programs, has been the more or less conscious feeling that in some way these innovations tended to degrade the worker by taking away his craftsmanship.

Large-scale industry, great population centers, extreme subdivision of labor, emphasis upon scientific procedure, and the tendency toward impersonal relations in industry have introduced certain difficult problems into modern industrialism. New methods of doing the job and new working and living environments

are developing within the ranks of wage earners certain stresses and strains which bid fair to make the workers feel that the individual is of little consequence, that the worker is only an insignificant part in a machine beyond his control and understanding.

In the next decade, industrial peace and productiveness will depend upon the application of the principles of industrial psychology. Human engineering rather than mechanical engineering, is to be the potent factor in industrial advance. Man is a bundle of conscious and unconscious impulses or instincts which must be reckoned with. Industrial methods often needlessly and heedlessly run counter to deep-seated, inherited, and not easily changed, instincts. A major problem of industry is to make conditions square as far as possible with human nature. In these days of education for all and of universal suffrage, all movements which tend to depress the great rank and file and to put its members in positions of irresponsibility, and loudly to proclaim the superiority of management and the investor group, tend to drive the masses into a cohesive group likely to take drastic and revolutionary action when appealed to by certain types of leadership.

In our modern industrial civilization, four potent forces may readily be discovered tending to make the individual feel insignificant. 1. Modern industrial life is dominated by machine technology. The machine standardizes and mechanizes the forms of human association. The development of large-scale and standardized industry introduced the impersonal element into business relations. It became easy for the management out of touch with the men, to look upon the worker and the machine he tended as being similar. The dignity and skill of the craftsman seemed to be lost in the strange atmosphere of the large shop; the worker felt that he was being transformed into a machine tender. The machine set the pace; the "iron man" appeared to dominate over flesh and blood. As a consequence, the worker began to feel resentful when known as a number or a cog. Under such conditions, a tactless foreman or higher-up boss may give orders in such a fashion that the worker is aggrieved. Many foremen and managers of the type believing in "driving" the workers under their supervision, feel that it is necessary to belittle the worker and the importance of his work in order to keep him "in his place." Again, a type of management is found in many large plants which ignores the individual and thinks of workers only in the mass. Under such conditions, the employee begins to nurse grievances, fancied or real; he becomes a stickler for his "rights." "Wrong behavior patterns" result.

Scientific management tends to "depersonalize orders"; the situation determines what orders must be given and obeyed. However, unless the reasons for "depersonalized orders" are made clear to the workers or their representatives, they will continue to resent incidents of the new order of things. Education of the worker and publicity as to the affairs of the company are essential to the satisfaction of the order receivers. The workers feel that the joy and pride in work has been stolen from them by the advent of the machine, scientific management and standardization. They demand that the thrill of craftsmanship and of individual worth be restored. Truly, the over-organization, the de-humanizing, of industry is on trial. If industry is organized so that the rank and file of workers are made to feel that they constitute cogs in a social machine, that they are a nondescript group of inferiors, they will find sooner or later a way to emphasize their importance. If men are working for themselves or if they clearly see certain advantages, they are willing to subject themselves to a considerable degree of routine, regularity and machine tending; but they rebel against

being made semi-automatons for the benefit of others.

There are interesting exceptions to the statement that machinery and large-scale production tend to make the worker feel that he counts for little. The locomotive engineer is recognized as holding a position of greater dignity and importance than the driver of the ox-cart. The operator of a gigantic traveling crane is looked upon as being far superior to the man with the old-fashioned wheelbarrow. With these and other illustrations in mind, may it not be asserted that our problem in regard to machine technology is due in part to the fact that many processes which are routine and monotonous have not as yet come under the sway of the machine? When a process becomes routine and the performer becomes almost an automaton, that process may readily become a job for a machine; but a way must be found to pass on to the workers a considerable portion of the benefits of increased production due to the introduction of new machinery.

2. As a consumer of the output of large-scale industry, the individual must take a standardized product at a fixed price. There is little or no catering to individual idiosyncrasies or individual bargaining. One of the famous Ford cars has been exactly like another; its price has been definitely fixed. Large-scale industry and wide markets go hand in hand. A wide market of necessity means a multitude of purchasers in practically all walks of life. Large-scale industry in order to live and to expand further must cater to the rank and file, to the so-called common man. In order to obtain enormous supplies, the mass of consumers must give up individuality in demand. Industry is not alone in manifesting this proclivity. Literature, amusement and politics also bend the knee to the great average.

3. Science does not emphasize the importance of the individual. "Science reveals the hard facts of nature in all their brutal realism." It offers nothing which caters to the self-esteem of man. Science makes the individual feel insignificant; he looks like a little wave on the sea of eternity. The masses do not understand scientific thought processes; and, consequently, there is an imminent probability of a new reaction against science. Utopias, socialism, communism and religious leaders offer a world in which the common man shall come into his own and in which the powerful, the wealthy, and the wicked shall be put down.

4. The great increase in population in the last century has also tended to belittle the individual; he is lost in the mass.

If industry is carried on so that the rank and file of workers are made to feel that they are a nondescript group of inferiors, if as consumers they are made to feel keenly the pressure of standardization and uniformity, if science tends to shrink the individual and if the increase in population also tends to bring about the same situation, the rank and file will ultimately discover a way of indicating their industrial significance. In order to avoid unrest and possible upheaval, students of industry should study methods of offering to the workers some opportunity for responsibility in connection with their jobs. One significant task of the individual executive is so to organize industry and to treat employees that opportunity is offered in the work-time for the expression of the instinctive impulse which has been called the "wish for worth," that each worker may feel that he and his work are of importance, significance, and worth in the industrial world. Successful industrial leadership can no longer rest solely upon technical and financial expertness; the industrial leader of tomorrow will be one familiar with the fundamental principles of human engineering and industrial psychology. The new type of industrial leader will be an engineer in industrial relationships.

THE PHYSIOLOGICAL ACTION OF RADIANT ENERGY

By Professor HENRY LAURENS
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GENERATIONS of laymen and physicians have somehow assumed that part of the undoubted beneficial effects of an outdoor life is attributable to sunshine, yet heliotherapy is just emerging from the most empiric of performances into the dignity of a scientifically justified and rationalized procedure. No clear scientific definition of the relationship between sunlight and health was attempted until the later years of the nineteenth century. In 1889 William Huntly stated that sunlight was the thing to counterbalance the evil of the filth and dirt surrounding the natives of Rajputana. In 1889 Finsen published his work on the influence of solar and carbon arc radiation on lupus. In 1890 Palm, an English physician, attempted to show that the geographic incidence of rickets is directly dependent upon the amount of sunlight available. Raczynski in 1912 furnished the first indubitable evidence of the beneficial effect of the sun's rays in experiments on puppies and concluded that the lack of sunlight was one of the causes of rickets. In 1919 Huldschinsky announced the curing of rickets and tetany by means of solar and artificial radiation and his work was soon abundantly confirmed. It has been established that light treatment is excellent for surgical tuberculosis and rickets, and the effects on many other diseases show that we have in this therapeutic measure a stimulant to general health. Skin diseases, chronic anemias, nutritional weakness and wasting in infants, chronic bronchitis, the debility following acute infectious disease, etc., are greatly benefited and the healing of refractory wounds of all sorts is accelerated. While darkness, when the diet is adequate, seems to exert no detrimental influence over long periods of time, the effects of the lack of intense daylight, if not of sunlight, quartz lamp or C arc radiation, when the diet is even slightly unbalanced as to Ca, P and vitamins A and D, on general physical well-being and nutritional conditions is abundantly evident. But while this has been clearly demonstrated, the physiological mechanism by which the results are produced is by no means established.

There is a lack of appreciation as to what radiation embodies, of how the radiation of the quartz lamp and of the C arc differ from that of the sun, of the importance of the intensity of energy, and its duration of action. It should be obvious that if we are trying to copy sunlight we should know something about it as well as about the energy emitted by artificial sources.

Radiation is the process by which energy is propagated through space. Light is radiant energy multiplied by its visibility. The expressions "ultra-violet light" and "infra-red light" are misnomers. Light is that agent, force or action in nature by the operation of which on the organs of sight objects are rendered visible. In other words, it is visible radiant energy. Ultra-violet and infra-red do not render objects visible and they are, therefore, invisible radiant energy.

The intensity of solar radiation is a very variable factor, changing momentarily, daily, seasonally and geographically. On entering the earth's atmosphere about 5 per cent. of the total radiation (1.93 g. cal. per sq. cm. per

min.) is ultra-violet, 52 per cent. visible and 43 per cent. infra-red. Owing to extinction and absorption, by the time the radiation reaches the earth's surface the relative amounts have changed and at average heights of the sun with a total radiation intensity of 1.0 to 1.2 g. cal. per min. per sq. cm. the distribution is approximately ultra-violet, 1 per cent., visible, 40 per cent., and infra-red, 59 per cent. (Dorno). Total intensity is primarily dependent upon height above sea-level, as well as upon seasonal and daily variations, which particularly influence the ultra-violet. Abbot shows that only 75 per cent. of the total solar radiation (the solar constant) reaches a level of 1,800 meters and only 50 per cent. to sea-level. Dorno reports that the variations in the extent of the sun's spectrum into the ultra-violet from summer to winter at midday average 10 mμ, and through the year, from morning until night, about 20 mμ. Summer midday sun is only 10 per cent. richer in infra-red than in winter, in the visible red it is 45 per cent., in the green 90 per cent., in the ultra-violet 1,000 per cent.

The emphasis is always placed on direct sunlight, notwithstanding the fact that skylight has been shown to contain from two to four times as much ultra-violet as does direct sunlight. The influence of skylight has not been studied very much, but Tisdall and Brown find that December skylight in Toronto has a curative and preventive influence on rickets almost as marked as that obtained by exposure to the available sunlight, and Laurens and Sooy obtained similar results on the growth and blood picture of rats in New Haven throughout the year.

The energy emitted by various artificial sources varies not only in spectral distribution but also in intensity as to wave-length, so that comparisons of results obtained from different sources can at best be only very general and superficial unless the total radiant energy as well as that of the various spectral subdivisions is specified in absolute units. If a standard arc, such as an Fe or C arc, be used, such specifications as nature of source, distance from subject and duration of exposure might be regarded as sufficient. But when the Hg arc is used these simple specifications are meaningless. Different Hg lamps vary much in intensity and in the spectral distribution of their energy output. With use they show deterioration, so that even when the energy input is kept constant, which is not often the case, the energy output is increasingly inefficient, particularly with reference to the ultra-violet component.

Of the many sources the sun, the Hg arc in quartz and the C arc burning solid or cored carbons filled with mixtures of rare earths are of practical importance. There is a common belief that the radiation of such sources is solely or mainly active because of the ultra-violet fraction. This may be so, but it has been demonstrated in only a few instances, such as the cure and prevention of rickets, and the formation of melanin in the skin. On the other hand, there is much evidence that the effects are due to the entire spectrum.

I prefer the C arc to the quartz Hg lamp because the rays from the former are more like solar radiations than those obtained from any other source. The Hg lamp is proportionately high in ultra-violet but emits much less heat and visible rays and the short rays, in spite of their intense surface action, have poor penetrating power. It is rays about 300 to 320 mμ long which are most active in producing pigmentation, and they are the ones that are intensified in action by visible or heat rays in the case of the sun and the C arc. These sources produce flushing of the skin during exposure, while the quartz Hg lamp produces no sign of erythema until hours later. The pigmentation produced by

quartz Hg vapor lamps is generally admitted to be inferior to that produced by the sun or the C arc. On the other hand, there is evidence for expecting therapeutic results with other combinations of light rays, certain forms of tuberculosis responding more readily to sources of great intensity in ultra-violet radiation than to solar radiation (Mayer).

There are several methods for determining the amount and character of radiation from different sources. Those based on photochemical reactions are, in general, cumbersome and inaccurate. But one, that of Clark, wherein use is made of the effect of ultra-violet light on lithopone, gives promise of practical value. Pohle uses the photochemical method of Bering and Meyer, in which a solution of hydriodic acid in water frees iodine under the influence of intense radiation. However, at present, the thermoelectric is the logical method of procedure, measuring the intensity of the radiation in absolute units with a non-selective radiometer (thermopile and galvanometer), which can be calibrated by means of a standard of radiation.

Comparison between sources shows the importance of specifying the percentage distribution of the energy emitted. An air-cooled quartz Hg vapor-lamp has a percentage distribution about as follows: 30 per cent. ultra-violet, 53 per cent. visible and 17 per cent. infra-red. In the water-cooled lamps the ultra-violet equals the visible. The energy of a 28 Amp., 60 to 65 volts, flaming C arc is 15 per cent. ultra-violet, 59 per cent. visible and 26 per cent. infra-red. Sunlight at sea-level contains from 1 to 4 per cent. ultra-violet, 42 to 53 per cent. visible, and 57 to 43 per cent. infra-red. Sunlight on Mount Wilson (1750 M) contains from 2 to 5 per cent. ultra-violet, 50 to 55 per cent. visible, and 48 to 40 per cent. infra-red; and on Mount Whitney (4420 M), 2 to 6 per cent. ultra-violet, 54 to 55 per cent. visible, and 43 to 39 per cent. infra-red. We now measure at New Orleans not only the C arc radiation which we use but also sunlight, photographing the spectrum to determine the shortest waves emitted according to season and determining the total energy and its spectral distribution by means of a pyrheliometer.

Owing to the fact that ordinary window glass absorbs wave-lengths shorter than from 320 to 330 mμ there have been developed in recent years, in imitation of quartz, a number of substitutes for window-glass, letting through a considerable proportion of the ultra-violet of sunlight. Some of these are the Corning glass Corex, Vitaglass, Quartzlite glass, paraffin cloth glass, wire-mesh screen glass (celluloidinous material), flexoglass, celoglass, etc.

The appearance of the skin after irradiation with energy containing ultra-violet, visible and infra-red rays is familiar to all. The almost immediate reddening is due to radiant heat (infra-red and luminous rays), frequently has a mottled appearance, is not restricted to the irradiated parts of the skin and disappears soon after the irradiation. It is followed in a few hours by inflammation due to the action of the ultra-violet rays. The usually diffuse and homogeneous redness of this inflammation is confined strictly to the irradiated part and, according to the intensity of the radiation, may be combined with blistering and hemorrhage. The dermatitis is a pathological outcome of the physiological reaction of the skin.

"Light" erythema and pigmentation are the results of action of ultra-violet, but total solar radiation favorably influences the extent and duration of pigmentation, pigment produced by sunlight being of better quality and lasting longer than that produced by either the Hg or the C arc. Pigment is formed by the action of the ultra-violet in sunlight

so that wave-lengths longer than 290 mμ must be effective. Sunlight through glass which cuts off wave-lengths less than between 320 and 330 mμ produces only a slight degree of pigmentation.

Skin pigment probably serves as a screen, reducing the action of ultra-violet and increasing the absorption of visible and infra-red rays by converting them into heat. It does not fluoresce and is not a sensitizer. While it may be, and usually is, an index of the progress of treatment, it does not seem to be necessary to the cure. It is formed particularly following the action of wave lengths from 295 to 305 mμ. One school, represented by Rollier, Lo Grasso, etc., regards pigmentation without erythema as ideal; another avoids pigmentation by irradiating at long intervals but seeks to produce by massive doses as severe an inflammation as possible (the Copenhagen group, Reyn, Sonne, etc.).

There is a general belief that irradiation, particularly with a C arc, produces a greater or less drop in blood pressure, and this has been substantiated in my laboratory, and irradiation with a C arc may represent a form of treatment for some types of hypertension. We have studied the blood pressure, pulse rate and temperature of normal dogs following irradiation with a strong C arc. A maximum decrease of between 15 and 20 per cent. in systolic, and of 10 per cent. in diastolic, pressure occurs after the fifth exposure and reoccurs following subsequent exposures, the normal values being usually regained within twenty-four hours after each exposure. Long lasting depression was obtained in some cases (white, short-haired animals), depressions of 15 to 20 per cent. in both systolic and diastolic remaining for a week and reaching normal on the twentieth day after the irradiations are stopped. The pulse rate usually increases, an average of 20 per cent., during irradiation but returns to normal soon after. Body temperature increases during irradiation by not more than a degree and soon returns to normal.

Many of the observations on the blood picture during and following irradiation have been made under the most diverse conditions: at high altitude, in the tropics, at sea-level, inland and on the shore; with the sun, the quartz Hg lamp and the C arc; on the well, the sick, on children and on adults. There is no wonder that the most diverse results have been described.

We frequently observe and comment on the pale anemic appearance of those working and living in poorly lighted rooms. But it does not necessarily follow that there is in these cases a change in blood constitution, for it is not the Hb content or the absolute number of reds which is decreased by lack of light, but the volume of blood going to the skin. Such anemic looking people often have a surprisingly high Hb content. The case is similar in the members of polar expeditions. Blood studies made during the long winter night show that, in spite of the pale, yellow-green color of the men, there is no change in the blood as long as the food is sufficient. Bernhard, however, is convinced of the harmful effects of the lack of light as exemplified in what he calls the anemic condition of those in the Alps who live on the shady side of the deep valleys as contrasted with those who dwell where they are reached by the sun's rays. Similar effects he claims are reported by many polar investigators, namely, that the Eskimos and members of the expeditions are, at the end of the long polar night, anemic, edematous and weak. Bernhard believes that the reason why changes are sometimes reported not to occur in the blood of members of polar expeditions is that the winters are spent in an illuminated ship and that the failure to find evidences of anemia in mine horses is due to the fact that the mines are artificially illuminated. But recent

observations on mules kept in very dimly lit, almost always dark, mines for from five to ten years show but a slight increase in reds and a corresponding decrease in Hb. The increase in reds is thought to be due to the very good and abundant diet and the hard work that the animals do, an increased metabolism, thus representing an over-compensation against any possible deleterious influence that the lack of sunlight may have.

White, short-haired dogs exposed daily, or at short intervals, to moderate or massive doses of measured C arc radiation show a primary increase of about 30 per cent. in blood volume, evident during the first exposure, accompanied on successive exposures by an increase of about 10 per cent. in red cell number and volume and Hb. The increase in reds is maintained in some experiments, in one animal for six weeks after the last exposure. The red cells in the post-irradiation period are smaller in size and usually of normal saturation. Post-irradiation rises in platelets are frequent, and there is often a post-irradiation decrease in leucocytes.

Although light may benefit general health objectively and subjectively there is no evidence that light baths influence specific immunity. Hartley showed that light baths have not the least effect on specific immunity, although they do increase the general resistance of the body to infection by increasing the bactericidal power of the blood. Van Allen and his coworkers have obtained indication of a relationship between the nature or character of light and the physical state and functional activities of animals and have demonstrated an influence on the course and character of malignant disease in rabbits. C. M. Hill and Clark conclude that the use of ultra-violet radiation is not justified as a general therapeutic agent and that there is little to support the belief that it is capable of increasing natural resistance in normal individuals.

The result of irradiating the organism is to produce, usually, a transitory increase in blood acidity, followed twenty-four hours later by increased alkalinity, which disappears slowly and may last for fourteen days. Fatal doses are always accompanied by acidosis. Man and animals, well and ill, are apparently equally affected and the action seems similar from the short ultra-violet to the hard X-rays. Irradiation produces marked shifts in the serum acid-base ratio as well as shifts in the body minerals. The initial transitory decrease in CO_2 combining power is characterized by an increased flow of acid into the blood; the later and long lasting stage of alkalosis, by an over-compensatory action on the part of the base shifting tissues (Kroetz).

From observations on children and adults at sea-level and at 500 feet in Switzerland, Leonard Hill and Campbell conclude that the rise in metabolism caused by heliotherapy *per se* is insignificant when compared with that caused by exposure to open air. But Kestner and his coworkers found that seashore and mountain sun (and quartz Hg and C arc lamp radiation) strongly and immediately increase gaseous metabolism by action on the skin. The increase is diminished if there is a simultaneous heating effect which brings the chemical heat-regulating mechanism into action. Fries shows that the improved appetite and weight of malnourished children following quartz Hg lamp irradiation is not due to concomitant rise in basal metabolism which, even after repeated exposures during periods of several weeks, does not vary more than 10 per cent. as a rule. She finds no change in the pulse rate and blood pressure as a result of exposure to therapeutic doses of ultra-violet rays. Eichelberger also observed no immediate effect on basal metabolism following solar and C arc irradiation, but Mason and Mason ob-

tained a decrease following irradiation with a quartz Hg lamp.

It is now established that there are four factors, Ca, P, a vitamin and radiation, the lack of any one of which plays an important part in the production of rickets in infants. Rickets is a disturbance in the metabolism of the growing organism of such nature that the salt equilibrium, in particular as regards Ca and P, in the circulatory fluids is disturbed and lime salts no longer deposit in the bones. Lime salts may not deposit because the ionized Ca in the blood is low, or because the ionized P is low, or because both are low (Park). Exposure to radiation or the administration of cod-liver oil stimulates the deposition of inorganic salts.

Rickets and osteoporosis are of similar origin, being the result of a failure to assimilate Ca and P at normal rates (Hart, Steenbock and Elvehjem). Irradiation can influence the storage of Ca and P and the equilibrium of these elements in the blood stream of mature animals in a way similar to the effects upon growing animals. The antirachitic factor works not only in the retention of Ca in rickets but also in the adult in which rickets is never observed. It represents specifically the organic agent which promotes normal Ca anabolism. It may cure rickets, it may promote growth, or it may simply prevent excessive loss of lime from the body. The specific capacity in which it functions depends upon the condition of the animal, both with respect to age and nutrition, and upon the composition of the ration furnished. When vitamins A and D are completely absent from the diet, radiation can not bring about normality in either growth or bone calcification, the degree to which they approach normality depending upon the pre-experimental store of the factor.

Intestinal absorption plays an outstanding rôle in the effects of radiation. During active rickets considerable amounts of Ca and P are absorbed from the bowel and reexcreted into it. Irradiation prevents much of this abnormal reexcretion as well as promoting absorption from the intestine. The mechanism by which the absorption from the intestine is increased is influenced by two factors, the reaction of the gastro-intestinal contents and the fat intake, as in cod-liver oil. Alkalies diminish mineral absorption, while acids increase it. In infantile tetany, which often complicates the low Ca type of rickets, the acidity of the gastric contents is decreased with consequent decreased Ca absorption, returning to normal with the disappearance of the symptoms. The absorption of Ca is initially dependent on the free acid of the gastric juice, affecting the solution of Ca salts in the diet, and is normally restricted by the alkaline reaction of the intestinal secretions which tend to neutralize and so precipitate lime as insoluble phosphate. It is obvious that the beneficial action of radiant energy and of cod-liver oil is not limited to the rachitic processes. Their action is by supplying something which makes metabolism more efficient, causing the organism to operate with increased economy. They do not bring new processes into operation, but rather permit the organism to have full use of processes which are natural to it but not effective at the time.

Infantile tetany is a condition often complicating rickets and is a symptom complex which occurs in rickets when the salt equilibrium in the blood happens to be of a kind which sets the nervous system in a state of hyperexcitability, namely, low Ca, and it is with the low Ca form of rickets that manifest tetany is associated. Tetany is due to the taking away of Ca from the tissues, while in rickets there is an inability on the part of the bones to bind Ca. Irradiation with a quartz Hg lamp may lead to more marked manifestations of tetany as long as the rachitic metabolic dis-

turbance exists and latent tetany may become manifest. The rachitic tetany sometimes seen at the beginning of treatment is due to the sudden demand for Ca. In florid rickets the blood Ca is practically normal and falls only when healing begins, due to increased need during healing which is met by drawing upon the Ca in the other tissues. It is thus advisable to administer Ca along with the first irradiations. Manifestations of spasm, tetany and convulsions in the early spring may thus be due to sudden and prolonged exposure of children to strong sunlight.

The question as to whether irradiation of the mother produces a protective quality which can be transmitted through the milk has received considerable attention and has been demonstrated to occur in a number of animals and in man. It has been found that sunlight of summer intensity in England has no significant effect in raising the growth promoting value of cow's milk when the diet of the cow is deficient in fat soluble vitamins but does appear to have a small effect in determining the antirachitic value of the milk given. The vitamin A content depends on the diet, but the vitamin D content depends principally upon the degree of insolation of the cow. On the other hand, Hart, Steenbock *et al.* are of the opinion that, either indoors or in direct sunlight, the Ca equilibrium of milking cows is best established by increasing the Ca level and they believe that ultra-violet radiation is not, through direct impingement on the animal, a factor of consequence in the Ca and P metabolism of the dairy cow. Hess reports the production of antirachitic human milk by irradiation of the mother. Rickets was induced in rats after which 25 cc. of human milk was substituted for the rickets-producing diet with no beneficial results, the inorganic P remaining very low. The woman was then irradiated for a month with a quartz Hg lamp. The milk then fed to a lot of rachitic rats had very beneficial results, healing taking place with marked calcification of the epiphyses and increase in inorganic P. This is of some interest when we realize that rickets occurs in from one third to one half of breast-fed infants in the temperate zone.

Of more than usual interest is the demonstration that certain substances inert, in so far as antirachitic, bone calcifying and growth promoting power are concerned, may have these capabilities bestowed upon them by irradiation (Hess, 1924; Steenbock and Black, 1924). The fact that organs such as skin, liver, lung and muscle, as well as body products such as eggs, milk and feces have calcifying and growth promoting properties imparted to them is a matter of scientific and clinical importance. That an animal when irradiated has constituents in its body affected in such a manner that they become antirachitically active has far-reaching implications in connection with our ideas as to the mode of action of radiation, as has the fact that diets which are deficient in certain respects may be made complete by irradiation or by the addition of irradiated substances. A list of the substances which have been activated includes: olive, linseed, cottonseed, corn and nut oil, cholesterol, phytosterol, skin, dextrin, wheat, wheat flour, milk, milk powder, chicken mash, hay, spinach, lettuce, orange juice, yeast and sawdust. Some of the things which have proven refractory to activation are: a solution of chlorophyll, Hb, red blood cells, cream, oleic acid, egg phosphatide, mineral oil, casein and agar.

The presence of cholesterol and its derivatives in the skin and its fatty secretions and the easy absorption by the skin of fats rich in cholesterol, as well as the fact that isolated skin can be antirachitically activated, all imply that a vitamin activated in the skin by radiation is absorbed by the blood stream.

Ergosterol (an optically active sterol possessing three double bonds and a hydroxyl radical), a recently discovered product of great potency, is, in all probability, the naturally occurring parent substance of vitamin D. When irradiated with a quartz Hg lamp it has antirachitic action when as little as 0.003 mg. per capita is fed to rats. Approximately 1 mg. of cholesterol is needed to initiate healing. Ergosterol has the same characteristic absorption spectrum as non-purified cholesterol, the intensity of absorption, however, being enormously increased. Heilbron, Kamm and Morton believe that ordinary purified cholesterol contains another compound in small quantity with well-defined absorption bands (at 293, 280 and 260 mμ), while cholesterol itself has only general absorption. These bands disappear on irradiation with concomitant appearance of antirachitic potency, so that it seems as if the unknown substance is closely connected with the precursor of vitamin D.

In connection with the activation of skin cholesterol, recent work, showing that the efficient agent can be absorbed otherwise than through the intestinal wall, intraperitoneally, cutaneously, subcutaneously and intramuscularly, is of interest. The identity of the influence on Ca metabolism of exposure to ultra-violet and the administration by mouth of cod-liver oil is due to the fact that there are two methods by which the body may acquire the same "antirachitic factor"; that by the action of radiation this substance can be formed either in the cells of the living creature or in its foodstuffs and that many substances can be imbued with the antirachitic factor by exposure to radiation.

It is extremely difficult to formulate any all inclusive scheme of the action of radiation on living organisms. The effects for which we have explanations, based particularly on analogy with non-living substances, are either physico-chemical or chemical in nature. Between the two there are many phenomena which are only explicable on the basis of a shift from one to the other of these two points of view.

There are indications that radiation can act in more than one way; it may inhibit pathologic processes or destroy pathogenic organisms; or it may conceivably promote some of the bodily functions that are perhaps dependent on a stimulus from without. Finsen at first thought that the radiation with which he cured lupus acted as a bactericide. Later the question arose as to whether the radiation did not act rather as a stimulant to the tissues.

Irradiation acts first directly on the skin, causing an increase in permeability, precipitation of cell proteins and changes in the lipoids; secondly, it may influence the capillary endothelium and nerve endings; and thirdly, it may directly affect the blood proteins.

The therapeutic action of radiation has been regarded by some as due to heat produced locally by absorption, thus speeding up certain processes with no harmful raising of body temperature. Sonne holds that the view that the therapeutic effect of the universal light bath (arc lamp) is essentially due to the ultra-violet rays is not sufficiently warranted and believes that the curative effects are due to the capacity of the luminous rays to heat a very essential portion of the aggregate blood volume of the organism to a temperature possibly exceeding the highest ever measured fever temperature, without causing the body temperature, owing to its heat regulating capacity, to rise to any measurable degree. The specific heat of this blood circulating in the organism acts as a curative agent.

Another view regards the various effects as due to chemical changes in the skin, which bring about influences on distant parts either by reflex action or by diffusion into the blood stream and

transport to the parts affected. Cellular degeneration is a frequent sequel to irradiation of tissues and excessive action of radiation floods the body with too much of the products of tissue damage. Lewis has shown that the action of ultra-violet radiation on cutaneous vessels like other agents such as freezing, burning, etc., which cause tissue injury, sets free in the skin vasodilator substances with histamine-like action which diffuse into the surrounding skin to be then conducted away by lymphatic channels. The vessels become dilated because they lose contractile power and are more or less irresponsive to vasoconstrictor substances and to histamine.

One conception of the effects of radiant energy upon living matter is that the heat effect is due to increased molecular motion while the effect exerted by wave-lengths shorter than about 295 to 300 mμ is due to direct atomic disintegration of the molecules with immediately resulting chemical changes. The effect of radiation of given wave-length is directly proportional to the coefficient of absorption of the protoplasm for that wave-length. All radiation transfers energy to molecules which absorb it and produce heat, but certain frequencies fall into step with the oscillation periods which depend on the molecular structure and so break up the molecule when the energy absorbed is sufficient. The particular kind of radiation which produces this direct action depends on the character of the molecules.

With simpler chemical substances radiation acts as a powerful oxidizing and reducing agent and it may do so with the more complex chemical compounds in the living cell. All photochemical reactions are initiated by a change in configuration and velocity of the electrons of the substance absorbing the radiant energy. If the incident energy has small enough wave-length to produce vibrations in the electrons, instead of in the molecules and atoms, the absorption of energy may result in the activation of electrons. The activated electrons may be ejected, in which case the molecule is ionized, or the electrons may be displaced to an outer orbit, in which case the atom or molecule is activated. In either case they will show altered chemical reactions.

The pathological action of radiation consists in the knocking down of the entire arrangement of the electrons so that their proteins attain an isoelectric state and coagulate. But, even if the effects of irradiation are photoelectric, it is clear that radiation produces some substance or substances in the skin which eventually pass to the blood, so that all the observed effects are the expression of photochemical change.

As a recent editorial in the *Journal* of the American Medical Association pointed out, a demonstrated remedial agent is often liable to be magnified, by the enthusiasts on the one hand, by the unscrupulous on the other, into a universal panacea. Undue exposure to the sun's rays as well as other forms of radiation is by no means an innocuous experience. Inflammatory conditions are familiar as a reaction of excessive sunlight with the production of dermatitis solare. They have usually been attributed to the ultra-violet part of the spectrum.

More or less prolonged exposure to the violet and ultra-violet rays of the sun, and naturally to those artificially produced, may cause not only systemic disturbance but also inflammatory and degenerative changes in the skin, varying with the person. The harmful systemic effects have not been well understood, but deaths following short exposure to ultra-violet radiation have been reported. From a cutaneous standpoint, persons with a mild or moderate susceptibility to ultra-violet and, as has been shown, to the visible violet rays of the spectrum, are not uncom-

mon; severe reactions, however, are rare. Yet it is important to recognize that under certain circumstances a potential susceptibility or an existent cutaneous disturbance due to light sensitization may be made decidedly worse by artificial ultra-violet radiation. Under normal conditions, photosensitive substances are present in living tissue. Under abnormal or pathologic conditions an increase may occur in the amount, or perhaps in the development *in vivo*, of a new photosensitive substance with resultant photodynamic effects from light previously harmless. Since ultra-violet radiation is universally toxic for living cells, these, when hypersensitive to visible light, are apt to develop fulminating effects under such radiation. The basic cause of these effects is said to be a photochemical reaction, the intricate nature of which, however, is not understood as yet.

With the exception of the occurrence in the urine of a decomposition product of Hb there are no diagnostic signs or symptoms of the presence of a potential light sensitization in very young children. When ultra-violet therapy is to be administered to infants, testing doses, to determine tolerance or sensitivity, are therefore advisable. In older children, however, a recurrent eruption on exposed surfaces, particularly if associated with scarring, should be viewed with suspicion.

As Mayer points out, light of any form by itself is not curative but comprises only one of the important adjuvants in treatment. To believe that sunlight or artificial radiant energy will cure; to be unduly optimistic about this treatment and to consider it a specific form of treatment; to use it without sound medical guidance and adequate equipment, and finally to employ it to the exclusion of rest and hygienic-dietetic regimen is bound eventually to dishearten many and to bring discredit to an otherwise desirable method of treatment.

THE INTERIOR OF A STAR AND HOW IT MAINTAINS ITS LIFE[1]

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THE remarkable developments during the past few years in the application of modern discoveries in the structure of matter to the problems of the constitution and operation of the sun and stars form a most fascinating story. I am using the word operation advisedly, since the stars are great engines pouring out radiation at a tremendous rate and constantly renewing their energies from sources deep in their interior. Even at our distance from the sun of 93,000,000 miles, the earth is receiving one horsepower of energy on each square yard of its surface, and were our sun as hot as many of the other stars this amount would be greatly increased. So one of the fundamental problems of physical astronomy is to learn how these huge celestial machines are constituted, what is the nature of the physical forces which govern them, and how matter is modified at the enormous temperatures and pressures to which it is subjected in the stars.

Much of the theoretical and mathematical work on this problem has been carried on by a brilliant group of English physicists, notably Professors Eddington, Jeans, Fowler and Milne, and in this country by Dr. Russell, while the principal American observatories have contributed a large part of the observational material upon which the theoretical groundwork was laid. In trying to place before you some of the results of these extensive investigations I shall make no attempt to treat them individually, but rather to outline in a simple way the general conclusions to which they lead us as regards the dynamics of stars, their evolution, and the time-scale within which their changes occur.

At the outset it is desirable to emphasize the remarkable uniformity of nature so far as concerns the materials with which we have to deal. In the most distant stars and the remote universes of the spiral nebulae we find the same elements with which we are familiar upon our earth and which we recognize so easily in our sun. Even in their relative proportions they do not seem to differ greatly, and if we could imagine our earth heated through the successive stages ranging up to that of the hottest stars we could match it at almost every stage with some star within our field of knowledge. So the atoms with which we have to do are the same atoms which we know in our physical laboratories, but under the influence of such extraordinary conditions, especially in the interior of stars, that they are modified almost beyond recognition.

It is a rather interesting coincidence that physically a man is nearly a mean proportional between an atom and a star. It requires about 10^{27} atoms to make a human body and the material of 10^{28} human bodies to make an average star. An atom is less than one one-hundred millionth of an inch in diameter and bears nearly the same relationship in size to a golf ball that a golf ball bears to the earth. Small as this volume is, we find within it the complicated structure of the atom with a central nucleus surrounded by rings or rather shells of electrons revolving about it in definite orbits very similar to those of the planets about the sun. We can then picture an undisturbed atom as a minia-

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ture solar system in which the distances of the electrons from the nucleus are quite comparable with the distances of our planets from the sun, but in which the velocities of revolution are enormously high, an electron making a million billion complete revolutions each second. All electrons are alike, being simply the natural units of electricity, but their number differs for each element and defines most of its properties. Thus hydrogen has but one electron, while iron has 26 and uranium no less than 92.

In spite of its extraordinarily small mass, which is roughly the fraction of a grain represented by 1 preceded by 25 ciphers, the energy possessed by an electron in any one of its orbits is a small but definite quantity. In the earlier theories of the radiation of energy it was supposed that light and other radiation was given out by an electron as it moved in its orbit, but it is now realized that radiation can be produced only when there is a change of energy, that is, when the electron jumps from one orbit to another and gains an excess of energy by the transfer. This excess it at once emits as definite radiation which may be visible to the eye, if it occurs within the range to which the eye is sensitive, or, if not, may be detected as heat or X-ray radiation. In other words, it produces a spectral line, the spectrum being simply an analysis of all the radiation which is given out by the excited atoms in a radiating body.

We see then that in order to excite an atom and so to produce radiation we must apply an outside source of energy to an atom sufficient to make its electrons jump from one orbit to another. This is done most simply through the application of intense heat, and the most convenient way of securing such heat in the physical laboratory is by the use of an electric current. So the element to be studied is vaporized by an electric arc, spark, or electric furnace, or, in the case of a gas like hydrogen, a current is passed through a tube filled with the gas at a very low pressure. In each case the application of this external energy disturbs the equilibrium of the electrons in the billions of atoms of the vaporized element, and they begin to jump from one orbit to another giving out radiation whenever the orbit into which they pass has less energy than that from which they started. All the electrons which make the same transition give the same radiation or the same spectral line, and since in the elements with many electrons a great number of different transitions are possible we obtain a spectrum rich in spectral lines. Even in the case of the simplest atom, hydrogen, there is good evidence that about 20 of these excited states can exist.

We can perhaps best illustrate these relations from the consideration of a very simple atom like that of hydrogen. Here we have only one electron revolving around a central nucleus. If an electric current is passed through a tube of hydrogen at low pressure, the electron is pulled out of one orbit into another and then flies back again. Since the inner orbit has less energy than the outer the electron has an excess of energy which it gives out in the form of radiation and produces a spectral line. It is as though the electrons were held by elastic strings which are momentarily stretched and then snap back into place. Hydrogen with its single electron has a comparatively simple spectrum, but iron with 26 electrons has some 2,000 lines in the visible spectrum.

If sufficient energy is applied from the outside, as in the form of a very powerful electric current or electric spark, it is possible not only to pull an electron out of its orbit, but even to detach it completely from the atom. In such a case the atom is said to be ionized and the character of its radiation, or its spectrum, is modified profoundly. It

has been found possible in the physical laboratory to detach as many as six electrons from the atoms of one or two of the elements and thus to produce multiple ionization. Another method of detaching electrons from atoms is by bombarding a gas with atoms from a radioactive substance like radium. This gives off atoms of helium which move with a velocity of about 10,000 miles a second. A collision of one of these atoms with an atom or molecule of a gas results frequently in knocking off one or more electrons which are momentarily free, although they very soon combine with other atomic systems. Still another method of producing free electrons is by the collision of X-rays with atoms. X-rays are ether waves of extraordinarily high frequency of vibration, and when one of them strikes an atom a very frequent result is that an electron absorbs the energy of the wave and flies away from the atom in a wild career which ends quickly with its capture by another atom. I have referred to these processes by which free electrons are produced because they play an exceedingly important part in the mechanism of the sun and stars.

We can now pass to a consideration of how atoms behave in the huge aggregations of matter which form the stars. But before doing so I should like to review briefly a few of the facts which we know about the stars that constitute our stellar system. In the first place they are very numerous. Under good conditions the naked eye can see about 6,000 stars over the whole celestial sphere, while a small telescope will show several hundred thousand. A large telescope adds immensely to the number, and it is estimated that about one billion stars can be photographed with the 100-inch reflecting telescope at Mount Wilson. Every one of these stars is a self-luminous body like our sun, with a surface temperature ranging from about 2,000° centigrade (3,600° F.) in the case of the coolest stars, to about 25,000° centigrade (45,000° F.) for the hottest stars. Our sun has the very moderate temperature on this scale of about 6,000° centigrade.

The stars are extremely far away from us. The nearest star so far known, apart from our sun, is at a distance of 25 million million miles, and the most distant stars we observe are probably 20,000 times as far away as this. Because of this immense variation in distance, the brightness of a star as it appears to us is no criterion of how bright it actually is. It may appear bright because it is relatively near us, or because it is very bright intrinsically. Of the two brightest stars in the sky, Sirius, the Dog Star, is comparatively near, while Canopus, the famous star of Egypt, is very distant but enormously bright intrinsically, giving out about 10,000 times as much light as our sun. The great range in the intrinsic brightness, or what we might call the candle power, of the stars is one of the most interesting facts of astronomy. The ratio amounts to 750,000,000 for stars already known, which is about the difference between a candle flame and a powerful electric searchlight.

Another important fact about the stars is the great range of their size and densities. Our sun, which is a comparatively small star, has a diameter somewhat less than 900,000 miles and a mean density 1.4 times that of water. Among the stars, however, we find that Antares, the brightest star in the constellation of the Scorpion has a diameter 300 times as great as the sun, or about 250,000,000 miles, while its mean density is less than one one-millionth of water or below the lowest vacuum which we can attain with our air pumps in the physical laboratory. At the other end of the scale we find stars with diameters no larger than those of the planets in our solar system, only a few thousand miles across, but with densities ranging up to many thou-

sand times that of water and far beyond the density of any element which we know upon the earth. Our heaviest elements like platinum are only about 22 times as heavy as water.

It is a most significant fact that the giant stars like Antares of enormous size have a very low density, while the dwarf stars of small size like the faint companion of Sirius have a very great density, since this means that the masses of stars do not differ by any such amount as we should expect from their size or brightness. The same result is shown by observations of double stars, which afford a direct means of determining masses. The evidence all tends to indicate that the masses of stars do not show any great range, only a few hundredfold at most, while their luminosities, volumes, and densities differ by factors of hundreds of millions. The probable explanation of this fact, as of many of the others to which I have referred, lies in the extraordinary physical conditions present in the stars and in the profound modifications which atoms experience deep in the interior of these stellar furnaces.

A star such as our sun, which may be taken as a typical dwarf star of its class, is a huge mass of gas at a very high temperature. There can be little doubt that it is gaseous all the way through, for no elements could exist in a solid, or probably in a liquid form, even at the temperature of its surface which is about 6,000° centigrade. Above the visible surface of the sun extends an atmosphere of gases reaching up for thousands of miles, visible at the time of a total eclipse as a ring of light surrounding the disk of the moon. Beyond this in turn is the corona, extending out to a distance of hundreds of thousands of miles. The surface of the sun is, of course, exposed to the intense cold of space, and the only way in which the enormous loss of energy through radiation can be made good is through a constant renewal of the supply from the interior of the sun. So we are at once faced with the question: What can we learn regarding conditions inside the sun and the behavior of matter when subjected to the enormous temperatures and pressures which there prevail?

Our direct observational knowledge of a star is, of course, limited to but a very small fraction of its volume. To penetrate into its interior we must use what Eddington has called an "analytical boring machine," that is, extend our data by the application of general physical and mathematical principles. These show at once that the temperature in the interior of a star is to be reckoned in millions of degrees and the pressure in millions of atomspheres. What does an atom do under such conditions?

In the first place it is evident that all the electrons except the innermost ones will be stripped from the atom and that the interior of the star will be filled with free electrons which fly about in all directions and are detached and recombine with extraordinary rapidity. A second result of these terrific temperatures is that radiation in the interior of the star will be enormously intense and mainly in the form of very short waves such as X-rays. These ether waves seek to pour out toward the surface of the star like a great wind, but on their way they encounter the mutilated atoms and electrons of the closely packed gases which tend to obstruct their progress. The result is an outward pressure toward the surface of the star, the pressure of radiation.

All radiation exerts pressure. The lights in a room exert pressure against its walls, although at such temperatures as we can obtain in our laboratories the amount is very small. Its measurement by Russian and American physicists about thirty years ago was a remarkably skilful piece of accurate research. But when we pass to masses and tempera-

tures, such as the stars possess, the pressure of radiation becomes extremely powerful and may even counteract the force of gravity which holds the stars together. To illustrate, if we consider a series of spheres of gas with masses of 10 grams, 100 grams, 1,000 grams, and so forth, each differing in mass from the preceding by a factor of 10, we find that the pressure of radiation is quite negligible as compared with the forces which hold the mass together until we get into very large figures. When the mass reaches 10 with 32 ciphers, however, the pressure of radiation becomes a considerable fraction of the force of gravity, and beyond 10^{34} it exceeds it. At this point, then, we might expect something to happen, and in Russell's happy phrase "what happens is the stars." The mass of the sun is 2×10^{33} grams, or about 2×10^{27} tons. If a star were much less in mass than this, radiation would not be great enough to maintain its equilibrium, and, if it were much greater, it seems probable that radiation pressure would blow it apart. So we find that nature after all keeps an accurate account of the number of ciphers and does not tolerate much deviation from a definite model. In Eddington's opinion a mass range of five to one would include 90 per cent. of the stars.

Returning then to the interior of the star, we find a mixture of atoms, electrons and ether waves in the wildest state of agitation. An interesting picture is drawn by Eddington in one of his recent lectures at Oxford from which I should like to quote a single paragraph.

"Dishevelled atoms tear along at 100 miles a second, their normal array of electrons being torn from them in the scrimmage. The lost electrons are speeding 100 times faster to find new resting places. Let us follow the progress of one of them. There is almost a collision as an electron approaches an atomic nucleus, but putting on speed it sweeps round in a sharp curve. Sometimes there is a side-slip at the curve, but the electron goes on with increased or reduced energy. After a thousand narrow shaves, all happening within a thousand-millionth of a second, the hectic career is ended by a worse side-slip than usual. The electron is fairly caught and attached to an atom. But scarcely has it taken up its place when an X-ray bursts into the atom. Sucking up the energy of the ray the electron darts off again on its next adventure."

The result of this wild confusion in the interior of a star is that while the atoms and electrons are battered back and forth with little permanent change of position, the ether waves do make gradual progress toward the star's surface, and finally emerge, perhaps after thousands or millions of years, transformed at the lower temperatures of the outside of the star into the light and heat waves which the astronomer observes and by which he is enabled to test the products of the physicist's calculations.

A very interesting consequence of the conditions in a star's interior is the possibility of the existence of very high densities. As we have already seen, an atom is like a miniature solar system with the distances between the electrons and the nucleus comparable with those between the planets and the sun. In the case of our terrestrial atoms, then, the limiting density is reached when the outer electrons are nearly in contact, which occurs usually when our substance is in the liquid state. Thus a liquid is nearly incompressible. In the stars, however, where the outer electrons have been stripped off, the atoms can be packed very much more closely together and the density can rise to extraordinarily high values. If we could imagine a star in which the atoms had been robbed of all their electrons, so that nothing but the central nuclei remained, we should find densities millions of times greater than we know upon the earth. Probably

this does not occur in the stars since the innermost electrons of an atom can in all probability be detached only with the greatest difficulty. The loss of even the outer shells of electrons, however, is amply sufficient to make possible densities which at first thought seem almost fantastic to those who deal with matter under terrestrial conditions. Our evidence for the existence of such densities in the stars, nevertheless, is strong, and this in spite of the fact that the stars are wholly gaseous.

An interesting and in some respects unique means of testing the conclusions of physical theories of the densities possible in the interior of stars is afforded by the faint companion of Sirius, the brightest star in our sky. This star forms a physical system with Sirius, and hence we are able to determine its mass, which is nearly equal to that of the sun, and about two-fifths of that of Sirius itself, although its brightness (and in this case its real luminosity since the distances of the two stars are equal) is only 1/10000 part as great. For many years it was supposed that the companion was at a very low temperature, which would account for the small luminosity of a star of such large mass, but observations made at Mount Wilson about 13 years ago showed that its spectrum is very similar to that of Sirius itself. This left us with the choice of two alternatives: either that a star can have a spectrum which so far as we know is always associated with a high surface temperature and yet actually be at a very low temperature, an assumption which is repugnant to our scientific methods of thought; or, that the star is of very small size and hence, in consequence of its large mass, of extraordinarily high density.

A direct test of these alternatives is afforded by the theory of generalized relativity. This requires that there should be a displacement of the spectral lines which depends directly on the mass of a star and inversely on its radius. In the case of our sun, and most of the stars, this displacement is very small because the radius is large, although very accurate observations of the solar spectrum by St. John have proved its existence definitely. If, however, the size of the companion of Sirius is as small as theory would indicate, the relativistic displacement should be comparatively large and capable of observation. The problem was undertaken at Mount Wilson and the results found indicated the presence of the displacement in almost exactly the amount predicted by theory. The observations are difficult because the star is faint and involved in the glare of its brilliant neighbor, but there is as yet no reason to believe that the measurements are incorrect. They would lead to a radius for the star about 1/30 that of our sun and a density 36,000 times as great. This would be about 50,000 times the density of water, or 2,000 times that of platinum.

Densities even greater than this are indicated for one or two other faint stars in the sky, although direct observational tests such as we have for the companion of Sirius are lacking in their case. A faint star discovered by van Maanen is found to show a spectrum which points to a relatively high surface temperature, and a mass which, as derived from the relationship connecting mass and luminosity, is about one seventh that of the sun. The resulting diameter is about that of the earth and the corresponding density 400,000 times that of water. A cubic inch of such material would weigh no less than seven tons! Although stars of this type seem to be comparatively rare, there are great numbers which have an average density at least equal to that of solid iron.

The stars of which we have been speaking are all dwarf stars. If we pass to the huge giants, millions, and in some cases hundreds of millions of miles, in diameter, we find just the opposite state

of conditions. The mean density of the bright star Capella is just about that of our air, so that a human being could just breathe comfortably were he placed in the interior of Capella and were he not discommoded by a temperature of a few millions of degrees and an atmosphere consisting mainly of flying electrons. Inside of Antares he would find a density lower than that of the most perfect terrestrial vacuum and would speedily come to grief.

I cannot close this brief consideration of the densities of stars without a reference, once more taken from Eddington, to the remarkable consequences which would follow if we had among the stars a globe of the size of Betelgeuse and a mean density equal to that of the sun. We have already seen that its diameter is about 200,000,000 miles and its density about one-millionth that of water. If it had a density 1.4 times that of water, which is the average density of the sun, three results would follow according to the modern theory of gravitation:

"First, owing to the great intensity of its gravitation, light would be unable to escape; and any rays shot out would fall back again to the star by their own weight.

"Second, the relativistic displacement would be so great that the spectrum would be shifted out of existence.

"Third, mass produces a curvature of space, and in this case the curvature would be so great that space would close up round the star leaving us outside—that is to say, nowhere."

Eddington concludes by remarking "except for the last consideration, it seems rather a pity that the density of Betelgeuse is so low."

Perhaps the most fundamental of all the questions connected with the physical processes in the stars, and at the same time the most difficult to answer, is what keeps up the enormous supply of energy. For many years it was believed that the contraction of the stars, with the resulting conversion of mechanical energy into heat and light, was the true explanation, but recent additions to our knowledge show that this is quite inadequate. An outstanding difficulty is that it does not give us time enough. In the case of our sun it gives us about 20,000,000 years back to the time of its origin, but this is by no means enough for all the processes of cosmological and geological time. Something like 1,000,000,000 years is much more nearly the minimum period required. For giant stars, which pour out their energy hundreds or thousands of times as fast as our sun, the period of life history is cut down to quite inadmissible limits.

So we are forced to seek another explanation, and one which will provide the source of energy in the interior of the stars themselves. Here we find a supply of enormous magnitude, and one equal to every demand upon it, in the energy of constitution of atoms and electrons, that is, in the positive and negative electric charges out of which matter is made. If this energy can be released, either in part by a redistribution of the electrons and nuclei into forms involving less energy, or in whole by a complete annihilation of the atoms themselves, the result will be a supply of inconceivably great amount.

The first of these two processes would result in the transmutation of the elements, such as is familiar to us in the gradual changes of radioactive substances. If several atoms of the simplest of all elements, hydrogen, were to be combined to form one atom of a more complex element, about 0.008 of the mass of each atom would be lost in the change and would be released in the form of energy. For example, if a pound of hydrogen were transformed into helium, an atom of which is made up of four hydrogen atoms, the result would be 0.992 pound of helium and 0.008 pound of energy. This last figure sounds very

small, but 0.008 pound of energy is rather more than 430 billion horsepower. So if we can think of the sun as originally a mass of hydrogen gas which has gradually been transformed into the various elements that we now find within it, the energy released in the process would keep the sun shining for about 10 billion years. The time-scale afforded in this way seems to be ample, even for the vast periods required by cosmological history.

If instead of concluding that a part of the atomic energy is released by the transmutation of elements, we assume that all of it may be made available by the complete annihilation of matter, our supply of energy would become very much greater. In this case our pound of hydrogen would give us a pound of energy instead of 0.008 pound, and our total supply would be multiplied by a factor of 125. Our sun, on this hypothesis, would be radiating away its mass at the rate of 120 thousand billion tons a year and the material now contained in it would be sufficient to maintain the present rate for about 15 thousand billion years longer. At the end of that time no mass would be left.

As between these two views of the source of energy of the stars, the transformation of matter and the annihilation of matter, there is perhaps not very much to choose. The latter would give us the larger supply and the longer time-scale. It would require that in the past the stars should have been much more massive than they are now, and this in turn would have favored their close approach and the conditions under which we believe our planetary system had its origin. In behalf of the hypothesis of the transmutation of the elements we may say that the very fact of the existence of helium and other more complex elements in the stars is good evidence for their possible formation from hydrogen in the great chemical laboratories which the interiors of stars provide. There is no philosophical view more deeply imbedded in the scientific mind or more complete in the satisfactions it affords than that of the development of matter, or of life, from the simpler to the more complex forms.

A very natural question to ask at this point is: Can the results of observation afford any evidence as to the destruction of matter in the production of radiation? In one very important respect it can. If a star loses mass by radiation the older stars in the evolutionary sequence should be less massive. This is just what observation shows. In the main chain of dwarf stars, which includes the great majority of stars in our system, a regular progression with age is found, the older stars being less massive, more dense, less luminous, and of a lower surface temperature. The fundamental discovery by Eddington that the luminosity of a star depends directly upon its mass shows at once that it can progress along the evolutionary sequence only if it loses mass. Otherwise, it will stand still at a point defined by the original quantity of matter in it. Even if we assume that energy is supplied by the transformation of elements, it is evident that a stage will be reached when the process will be complete, and the star will become extinct. On the other hand, if matter can be radiated away as energy, radiation will cease only with the annihilation of the star itself.

The picture then of the probable course of evolution of our sun which this theory gives us is about as follows: We may assume that at present it is in equilibrium, with the amount of energy radiated balanced by the supply of subatomic energy from the interior. As it loses mass it attempts to readjust its internal conditions to correspond. A drop in temperature takes place in the interior which reduces the supply of energy below the amount lost by radiation. The sun then contracts, the temperature rises, the energy increases, and the sun

regains its equilibrium. The process repeats itself again and again, each time resulting in a loss of mass and an increase in density. Our last clear view of it would be as a faint red star, of small mass and high density, one of the vast number of such stars which people our stellar universe.

One final consideration of profound interest is that of the possible reversibility of the process of radiation. If matter can be annihilated to produce energy, can energy recombine, as it were, to form matter? Of the energy poured out by the sun less than one two-hundred-millionth part is intercepted by the planets, and a quite negligible amount by the stars, while the flood of radiation from the stars themselves passes out into remote space quite unchecked except for the small quantities absorbed by the nebulae. Is it possible that radiation is finally reflected back from the boundaries of a limited space, or do we have in the nebulae some mechanism by which the energy released from matter can be stored up once more in the form of atoms and electrons? Such considerations are purely speculative, for we know of no process of this kind. If it does exist, we can picture our physical universe as renewing itself and perpetually changing; if it does not exist and energy is finally dissipated, the end will be that pictured in the first chapter of Genesis with "darkness upon the face of the earth."

In this brief outline of some of the more important applications of modern physical theory to the stars, I have not touched upon many of the difficulties which exist, some of which may modify considerably our present views. We can not weigh and measure the material in the interior of stars and can only extend to it the physical laws gained from the limited conditions of our laboratories. Broadly speaking, however, the picture of the stars which we obtain is a consistent and a most illuminating one. The progress of science is in large measure due to the bold and skilful investigators who do not hesitate to push their conclusions to the utmost limits, since only in this way can we learn the strength and the weaknesses of the foundations of our knowledge and test the firmness of the structure erected upon it.

FOUR OLD ASTRONOMICAL OBSERVATORY BUILDINGS

By Professor FLORIAN CAJORI
UNIVERSITY OF CALIFORNIA

THERE are three seventeenth century European observatories of permanent type which are of interest because of the record of discovery associated with them. We refer to the Observatories of Copenhagen, Paris and Greenwich. The observatory at Copenhagen was built by King Christian IV of Denmark, apparently as a reparation for the indifference to astronomy shown in the time of his minority by permitting the renowned astronomer Tycho Brahe to be deprived of his observatory at Uranibourg and to abandon his native country. The observatory at Copenhagen was completed in 1642, the year, as it happened, in which Galileo died and Newton was born. The inscription on the building is partly in words, partly in symbols and partly in abbreviation. The whole inscription, as interpreted in words by a Copenhagen official, Bering Liisberg, is: *Doctrinam et justitiam dirige, Adonai, in corde coronati Regis Christiani Quarti* (Guide the faith and justice, Oh Jehovah, in the heart of King Christian IV). The observatory constituted the tower of "Trinity," a student church at the university of Copenhagen. In 1728 this tower and church were damaged by the great fire of Copenhagen. The astronomical instruments in the tower were destroyed, including the famous celestial sphere of Tycho Brahe which had been sent back from Prague as booty in the Thirty Years' War. Astronomical observations were made in an apartment at the top of the tower. In the second half of the seventeenth century great changes took place in the design of astronomical instruments, in consequence of which the Copenhagen observatory as well as the one in Paris were found to be inadequate in design. When Roemer in 1681 returned from Paris to Copenhagen, he found that instruments at the top of the tower were disturbed by strong winds. He turned his private residence into a temporary observatory. However, astronomical work was carried on in the old round tower until the year 1861, when a new observatory was finished. The astronomer T. N. Thiele, whose son is now a mathematical astronomer at the University of California, was one of the last observers in the old round tower of Copenhagen.

The tower has been regarded a masterpiece of art and is still one of the attractions of the city. Visitors ascend 35 meters to the top by a spiral avenue. The tower consists of two hollow concentric brick cylinders, the interior one being about three meters in diameter, the outer one about 16 meters in diameter. Between these is the spiral avenue, made famous by the spectacular rides in 1716 made by Peter the Great of Russia and his Queen. The astronomer Horrebow states in one of his books that Peter the Great frequently ascended the tower on horseback along the spiral avenue, and that the Empress Catherine occasionally ascended at his side in a four-wheeled chariot drawn by six horses!

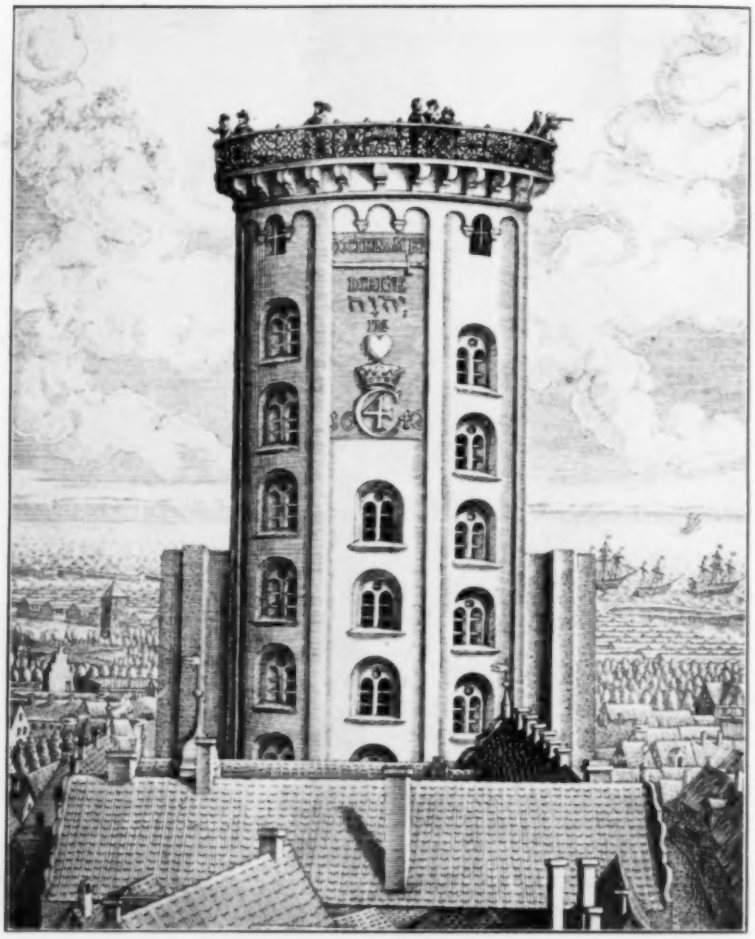
The Paris Observatory was begun in 1667 and completed in 1671. It was one of the enterprises carried out by Louis XIV and Colbert, his minister of finance.

for the glory of the reign. A great building and great astronomers added luster to French science. Christian Huygens was called to Paris in 1666, Jean Dominique Cassini came from Italy in 1669, Olaf Roemer from Denmark in 1671. Jean Picard was making his celebrated measurements of the earth which Newton used in testing the law of gravitation. The Paris Observatory was a stately edifice, planned by the architect Claude Perrault, noted for his colonnade of the Louvre. The observatory consisted of a quadrangular pile, flanked by two massive towers. In after years the flat roof was altered in appearance by the addition of several domes. Otherwise the building retains at the present time its seventeenth century appearance. Frequent criticism has been passed upon it because, as Robert Grant states in his "History of Physical Astronomy," "no means were provided in the construction of the building for enabling the astronomers to observe celestial bodies at all altitudes, by means of instruments sheltered under its roof, nor was it possible to repair this omission on account of the enormous thickness of the walls." The illustration of the building and grounds which we give is more instructive than other pictures of it that we have seen, for the reason that it exhibits more of the astronomical instruments then in use. We see here the old Huygenian type of telescope with a long tube. Achromatic lenses were then unknown. To enhance the magnifying power without excessive chromatic blurring of images, the focal length of the objective lens was increased. This necessitated telescopes with very long tubes. The figure shows also the old-fashioned clumsy quadrant. On a table is an armillary sphere. The picture bears testimony also to the interest in astronomy taken in early days by women.

The observatory at Greenwich has a somewhat different history than the ones

THE OBSERVATORY AT BOGOTA, 1803, THE EARLIEST PERMANENT OBSERVATORY BUILDING IN AMERICA

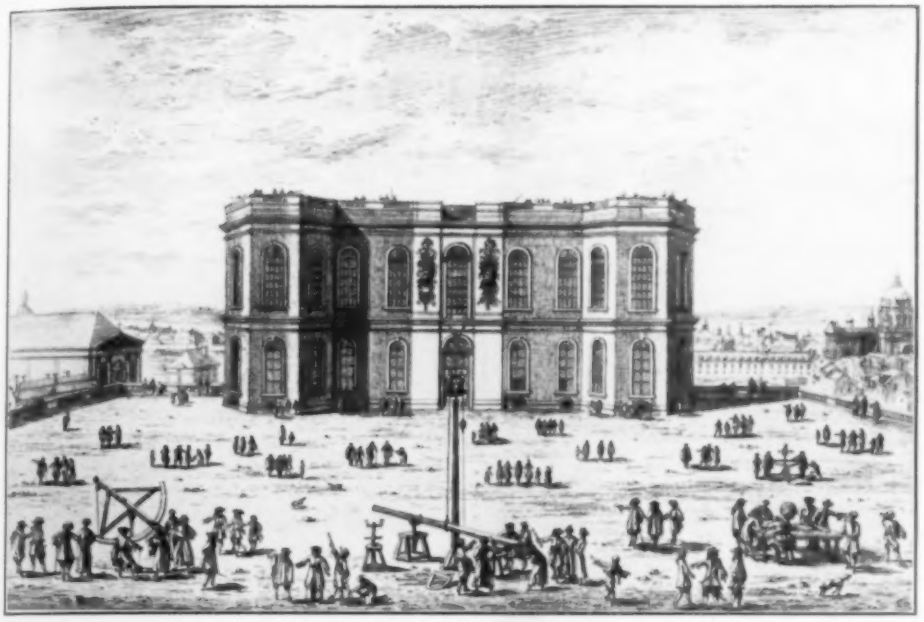
at Paris and Copenhagen. There was no marked attempt at architectural display; the structure was planned by the practical astronomer, Flamsteed, and the mathematician and architect, Christopher Wren. The motive which led to the initial steps for erecting the observatory was not to add fame to the reign of the King of England, nor to give luster to British science, but to serve the practical needs of British seamen. It was a time when navigation ceased to be confined to the Mediterranean and to the coasts of continents, when ships ventured into the unmeasured expanses of the great oceans. It became necessary to know the positions of ships, in particular, to determine the longitude of a place at sea. The method of "dead reckoning" was extremely inaccurate and inadequate. An amusing incident



THE COPENHAGEN OBSERVATORY, BUILT IN 1642 BY KING CHRISTIAN IV, AND STILL VISITED BY TOURISTS
(Courtesy of H. Thiele.)

is told of Commodore Anson who wanted to reach the island of Juan Fernandez near Chile to obtain fresh water and provisions. Believing that he was west of the island, he sailed eastward; really he was east of it and was sailing away from it as fast as the wind would carry him. The commercial position of Great Britain and its standing as a world empire depended upon its navigation. The Greenwich Observatory was erected to observe the motions of the sun, moon and planets and to secure accurate star catalogues that were needed for the more reliable computation of longitude. And yet, this observatory, built to answer practical needs, has contributed powerfully toward the advancement of science.

Greenwich Observatory was founded in 1675 in the reign of Charles II. "A gate-house demolished in the Tower supplied wood. . . . The sum of £500, actually £520, was further allotted from



THE PARIS OBSERVATORY, ERECTED IN 1667 BY LOUIS XIV

THIS PICTURE SHOWS MORE FULLY THAN OTHERS THE TYPE OF INSTRUMENTS USED BY ASTRONOMERS OF THE SEVENTEENTH CENTURY

the results of a sale of spoilt gunpowder; and with these limited resources Greenwich Observatory was built." Our picture shows the observatory in the days of Flamsteed, the first Astronomer Royal. "Whenever any part of it was found insufficient for its purpose," says Newcomb, "new rooms were built for the special object in view, and thus it has been growing from the beginning by a process as natural and simple as that of the growth of a tree."

Ask an astronomer which is the oldest permanent observatory building in America and he will probably make an incorrect reply. The oldest permanent observatory on our continent is at Bogota in Colombia, a city at one time considered "the Athens of South America." The observatory was erected in 1803 through the prestige and persuasion of the Spanish scholar José Celestino Mutis, a friend of Alexander von Humboldt. Mutis and Francisco José de Caldas, a native scientific enthusiast whom he had trained, took observations with instruments mainly of European construction. After the death of Mutis and after Caldas became a martyr in the cause of his country's independence from Spain, regular astronomical work ceased at Bogota for the larger part of the nineteenth century. It is for that reason that the observatory is not generally known to astronomers. But about the beginning of the present century scientific work was resumed and since 1922 special emphasis is placed at the observatory upon meteorological and magnetic observations.

The observatory at Bogota was an expensive structure for that day, costing 13,815 pesos. It was built for the advancement of science and also as an ornament to the capitol of what was

GREENWICH OBSERVATORY IN THE TIME OF FLAMSTEED, THE FIRST ASTRONOMER ROYAL

then New Granada. The design was made by the Capuchin Fray Diego Domingo Petréz. Caldas called the building "the first temple erected to Urania in the New Continent." It was an octagonal tower over 18 meters high. Our illustration exhibits the tuscan pilasters fitted to the angles of the octagonal structure. Prominent in our photograph is a tower on a side of the main octagonal part, which provided a spiral stairway to the upper floors.

THE PROGRESS OF SCIENCE

THE RETIREMENT OF DR. FEWKES

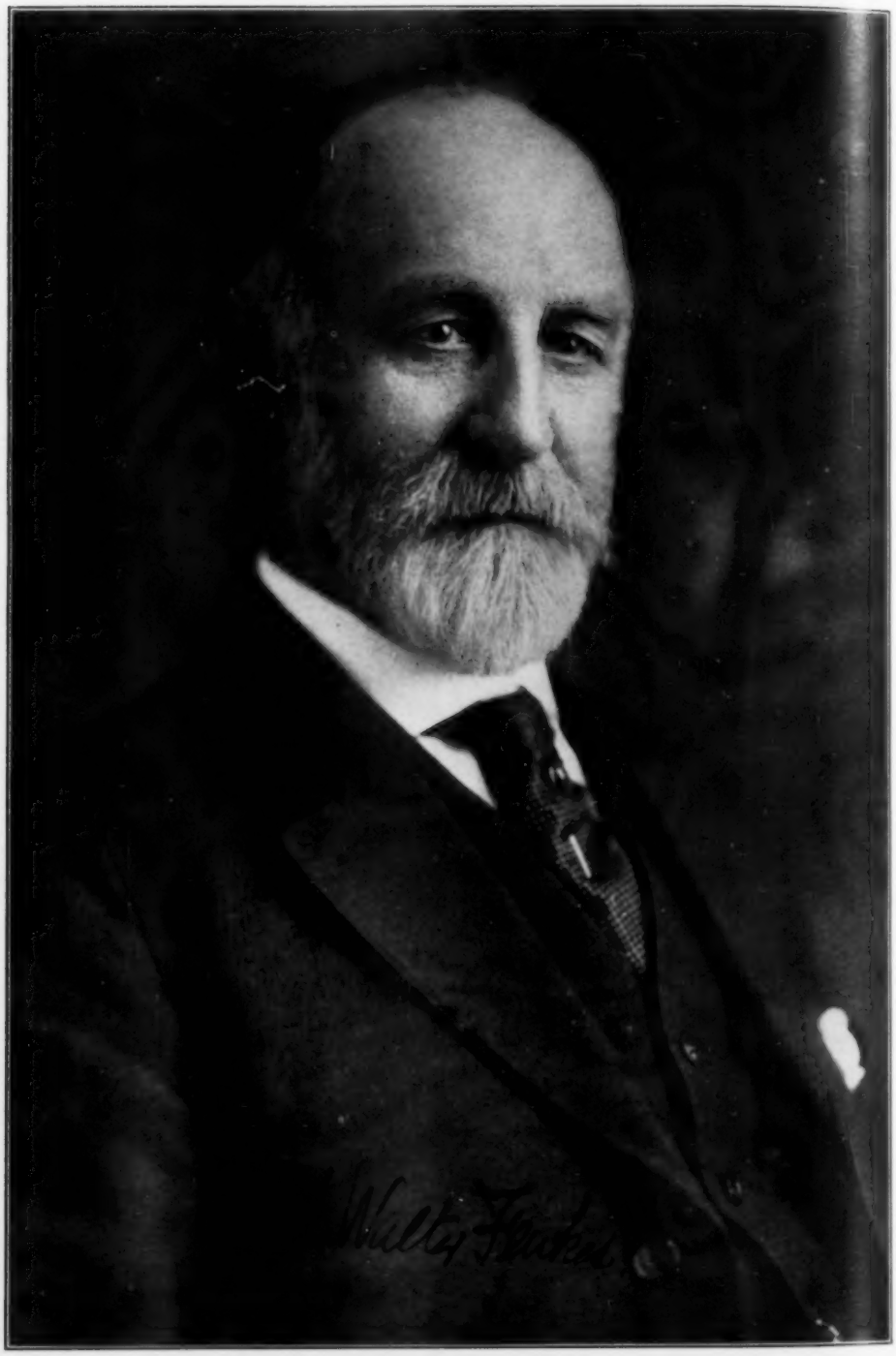
Dr. J. Walter Fewkes, chief of the Bureau of American Ethnology under the Smithsonian Institution for the past ten years, has retired as administrative head of the bureau and will devote himself entirely to research.

Dr. Fewkes is one of the few white men who have been initiated as a priest into the secret rites of the Hopi Indians. He was the first man to make use of the phonograph in recording Indian music. He introduced the principle of preservation into archeological research in this country, so that excavation of the ancient Indian monuments of the land was transformed from a looting operation to one of preservation. His work made Mesa Verde National Park a center of pilgrimage for thousands annually and a national show place. He gathered one of the largest and finest collections of Indian pottery ever brought out of the southwest. He founded and edited the *Journal of American Ethnology and Archeology*. On the immense quantity of data collected by him will rest much of the future work in American archeology and ethnology.

The retiring chief of the Bureau of American Ethnology is one of the few living disciples of the great naturalist, Louis Agassiz. As an undergraduate of Harvard University, Dr. Fewkes turned his attention at first to physics and published some results of original researches in electricity. In 1873, however, he attended the Agassiz School at Penikese Island, Buzzard's Bay, and for the next fifteen years he devoted himself to zoology, specializing in the lower invertebrates. He worked and studied both in this country and at Leipzig, Naples and in France. During most of this time he was connected with the Museum of Comparative Zoology at Harvard University.

A trip to California in 1887 gave the final bent to his interests by absorbing him in ethnological problems, especially of the Pueblos. In the summers of 1889 and 1890, Dr. Fewkes visited Zuni, New Mexico, and in the latter year first employed the phonograph in recording primitive music. He became deeply interested in primitive religion, and spent four years in the study of the ritual of the Hopi, in the employ of the late Mrs. Mary Hemenway. He was initiated into the Antelope and Flute priesthoods of the Hopi, and consequently witnessed and was able to describe for the first time many secret ceremonies of the tribe. In 1894 he published what now stands as the classic account of the famous Walpi Snake Dance. The Hopi gave him the name of "Naquapi," which means Medicine Bowl. They named him, so they said, because he was like a medicine bowl in that they were always pouring information into him.

Dr. Fewkes' connection with the Smithsonian Institution began in 1895 when he engaged in field work for the institution. He collected at Sikyatki pueblo, Arizona, one of the finest collections of pottery ever brought out of the southwest, distinguished by delicacy and variety of coloring and decoration, and perfection of form. Twenty years later he made another collection of prehistoric pottery from the Mimbres Valley, New Mexico, from which he was able to show the existence of an extinct people, possessed of the most realistic art of any people of the southwest. The decorations included live figures, humans, animals, birds and hunting scenes, as well as striking geometric designs.



DR. J. WALTER FEWKES

Retiring Chief of the Bureau of American Ethnology

The publication of Dr. Fewkes' first work under the Smithsonian marked the beginning of intensive archeological work on southwestern cliff-houses and pueblos. His outstanding archeological achievement among many is the excavation and repair, begun in 1908, of many of the cliff dwellings and temples situated in Mesa Verde National Park, Colorado. His work on Spruce Tree House and Cliff Palace, two of the largest cliff dwellings in the southwest, was one of the pioneer projects for the thorough excavation and repair of ruins in the prehistoric pueblo area. Aside from their value in connection with the prehistory of the American Indians, the restorations have made of the park a life-size museum from which thousands take away annually a more just conception of the culture of the people the white man displaced.

The number and extent of the researches and excavations which Dr. Fewkes has initiated as a pioneer give him perhaps a unique place in American archeology. They include work among the native peoples of Porto Rico and the West Indies, an archeological survey of the Gulf Coast of Mexico, excavations in Trinidad and the Lesser Antilles, and more recently investigations of Florida and South Carolina mounds.

Though retired from active service, Dr. Fewkes will retain a study in the Smithsonian with the Bureau of American Ethnology and continue his own researches, adding to his already imposing list of scientific publications. His successor as chief of the bureau has not yet been appointed.

AIRPLANE SAFETY

The new automatic slotted wings for airplanes, invented in England and now being given their first American trials on Navy planes, will reduce the aviation death lists considerably if their performance in practice lives up to their showing in tests. More than eighty per cent. of the fatal accidents in aviation are due to stalling, spinning and nose-diving. The automatic slots attached to an ordinary airplane cure the stall and tend to make the airplane safe.

"Stalling" is the nightmare of every pilot. Good ones or bad may stall their craft when they try to land too slowly, climb too quickly, or land a plane with a dead engine. When the flying speed of the plane reduces to a certain point, the "lift," or supporting force on the wings caused by the rush of the plane through the air, decreases. The plane then tends to slip backward, as it were, and the pilot can not make it obey the ailerons or other controls. It spins and plunges downward toward earth. If the pilot knows enough and is high enough when a stall occurs, he can eventually right and save his ship. But if the altitude is low or the pilot unskilled, a crash is practically sure to follow.

The Handley Page automatic slotted wings come into action when the plane is about to stall and become uncontrollable. They consist of slats or flaps on the front edge of the wings that, when the plane is flying normally, form a part of the wing structure. When the wing loses lift, however, the slat opens under the lifting force of the air on the slat itself. A slot is created in the wing and this so changes the characteristics of the airplane wing that it keeps the plane under control and prevents it from getting into a spin. Even an incompetent pilot can not stall his plane, according to claims made for the new device.

Slotted wings have been known for about ten years. Manually operated types were developed in England by the Royal Air Force and in Germany, but these had the disadvantage of needing action on the part of the pilot to put

them in operation. The Handley Page automatic slots were developed secretly in England and have only had limited demonstration there. The plane that has just been demonstrated here is so far the only one in America to be so equipped. It is an American-made NY training plane, as designated by the government, and equipped with pontoons to take off and alight on the water.

THE NINE-HUNDRED-THOUSAND-VOLT CATHODE RAY TUBE

In receiving the Edison Medal from the American Institute of Electrical Engineers for his work on lamps and X-ray tubes, presented to him in February, Dr. W. D. Coolidge, of the General Electric Company, announced the latest product of his researches, the triple-cascade cathode ray tube operating on 900,000 volts and capable of sending out into the air a stream of electrons with a velocity of 175,000 miles per second.

The new tube is a sort of three-in-one arrangement of the first tube Dr. Coolidge announced two years ago at the Franklin Institute, which operated at 300,000 volts. He tried building larger individual tubes, but found limitations to the voltage that could be used. He then tried out the cascade arrangement, whereby the rays from one tube would be fed into another, which would speed them up and feed them along to still another and in this way developed the 900,000 volts tube.

The electrons expelled from the tube, appearing in a ball of purplish haze, are shot forth at the rate of 175,000 miles per second, which is the fastest speed ever accelerated by man. This is about 350,000 times faster than the speed of a bullet shot from an army rifle.

"Just what the use will be for these high-speed particles obtained from the tube is still a problem," Dr. Coolidge says. "We shall experiment with them. They should eventually help us to further knowledge of radiation laws and of the atomic nucleus. It is not unlikely that therapeutic, chemical, bactericidal and other practical uses will develop."

The tube is about 95 inches long and has three bulbs, each 12 inches in diameter. The window from which the electrons are emitted is of thin metal foil, but one ten thousandth of an inch, or one quarter that of an ordinary piece of writing paper, in thickness. This is absolutely hole-proof and is so constructed as to withstand total atmospheric pressure of more than 100 pounds, the difference between the outside air and the almost perfect vacuum within the tube. A heated tungsten filament, originally used by Dr. Coolidge in his X-ray tubes, furnishes the supply of electrons. The glass tube is shielded with a copper tube so that the stream of electrons can not strike the glass and cause punctures.

"In our earlier attempts to build experimental X-ray and cathode ray tubes for voltages appreciably in excess of 250,000, we have seemed to be continually contending with and limited by the 'cold cathode' effect," Dr. Coolidge said. "More recently we have found that we can remove this limitation, by subdividing the total potential difference applied to the tube between different pairs of tubular electrodes. The electrons are then given successive accelerations as they pass between successive pairs of electrodes. This, in effect, divides the tube up into sections each of which may be good for as much as 300,000 volts. We have already successfully operated such a cathode ray tube with three sections on 900,000 volts.

"This cascade or multisectional system promises to let us build vacuum discharge tubes for as high voltages as we can produce. This applies as well to an X-ray tube as to a cathode ray tube, as the latter may be converted into the former by the addition of a suitable target. It also

HERMANN M. BIGGS

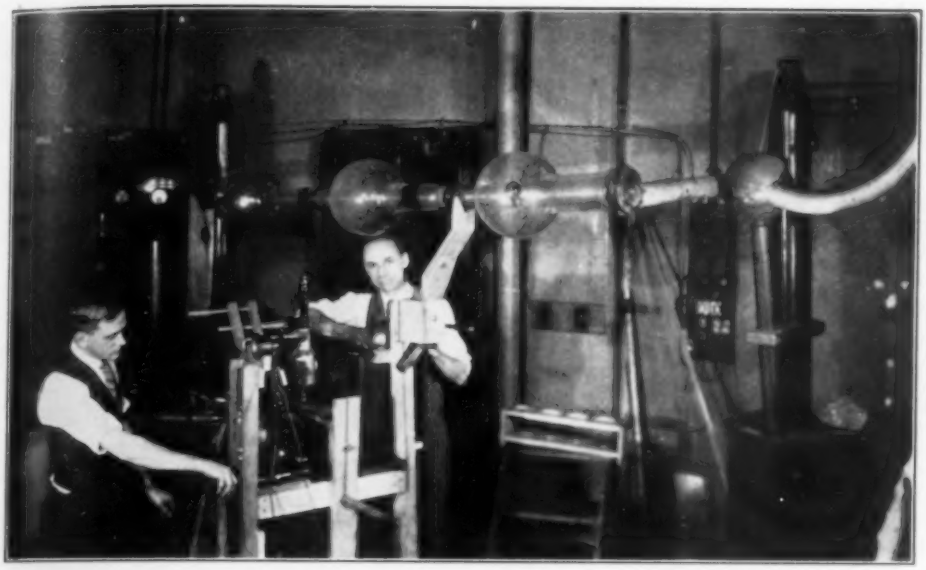
WHO AS PROFESSOR OF MEDICINE IN THE UNIVERSITY AND BELLEVUE HOSPITAL MEDICAL COLLEGE, CHIEF MEDICAL OFFICER OF THE NEW YORK CITY HEALTH DEPARTMENT AND NEW YORK STATE COMMISSIONER OF HEALTH, PERFORMED A SERVICE FOR PUBLIC HEALTH THAT WILL LAST LONG AFTER HIS DEATH.

DR. W. D. COOLIDGE

OF THE RESEARCH LABORATORY OF THE GENERAL ELECTRIC COMPANY, DISTINGUISHED FOR HIS WORK ON X-RAY TUBES AND CATHODE RAYS

applies equally well to a high voltage kenotron.

"This opens a vista of alluring scientific possibilities. It has tantalized us for years to think that we couldn't produce in the laboratory just as high-speed electrons as the highest velocity beta rays of radium and just as penetrating radiations as the shortest wave-length gamma rays from radium. According to Sir



THE NEW TRIPLE-CASCADE CATHODE RAY TUBE

Ernest Rutherford, we need only a little more than twice the voltage which we have already employed, to produce X-rays as penetrating as the most penetrating gamma rays from radium and three million volts to produce as high speed beta-rays. The intensity factor would be tremendously in our favor, as with twelve milliamperes of current we would have as many high-speed electrons coming from the tube as from a ton of radium in equilibrium with its decomposition products. Another factor in our favor would be the control which we should have of the output. This would be quite different from our position with respect to radium, in which case no physical or chemical agency at our command in any way affects either the quality or the quantity of the output.

"We expect to find that a high-voltage positive ray tube can be constructed along the general lines of the multi-sectional cathode ray tube. In this case, we should need, according to Rutherford, about eight million volts to produce positive rays having the energy of the highest velocity alpha rays from radium.

"The problem of vacuum-tube operation at very high voltages is a twofold one, as it involves not only the design of the tube but also the design of a suitable high voltage source.

"It seems quite possible that it will prove advantageous to proceed along the lines of our present oil-immersed X-ray outfit, in which the X-ray tube is placed in the same container and in the same oil with the high-voltage source. With such an outfit no part of the high-tension circuit is brought out into the air, and the corona problem is therefore greatly simplified.

"We now have transformers good for several million volts, even with the high-tension circuit brought out into the air, and it should be possible for us to go much higher than this if the whole high-tension circuit is kept in the oil."

A NEW ENGINEERING LABORATORY FOR LEHIGH UNIVERSITY

LEHIGH UNIVERSITY plans for the erection of a new Electrical and Mechanical Engineering Laboratory which will be one of the finest in the country. The new building will be the largest on the campus and will cost approximately a million dollars.

The laboratory will be collegiate Gothic in style with walls of native stone trimmed with cut limestone. It will have an over-all width of 225 feet and a depth of 184 feet. The largest division of the building is devoted to the main laboratory which will be occupied by both the mechanical and electrical engineering departments and will be spacious enough to accommodate the heaviest machinery, boilers, generators, etc. Ample provision is made throughout the building for offices and class-rooms, as well as numerous small research laboratories and others for the standardization of delicate measuring devices. An auditorium, a museum and library are additional features.

The new building will be provided with modern and fully-equipped machine shops. Four large drafting rooms are provided for the several branches of engineering drawing. A number of small laboratories will be devoted to the study of problems peculiar to electrical communication.

The laboratory is designed with lighting, heating and ventilation equipment of the most modern, efficient and effective type. The electrical engineering equipment will include a complete electrical sub-station, a high-voltage and traction laboratory and storage battery rooms. Special attention will be given to the installation of the multiplicity of electrical wiring in large conduits where they will be concealed.

President Richards' outline of the pressing need for this new building stresses the importance of laboratory work as an adjunct to the study of natural laws. Pointing out that Lehigh's enrolment in electrical engineering has increased 51 per cent. in the last three years, it is shown that the present laboratory facilities are rapidly becoming inadequate.